REVIEW OF INVASIVE ALIEN SPECIES MANAGEMENT

IN THE ALEIPATA ISLANDS, SAMOA

GEF-PAS Invasive Alien Species project/Samoa

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Photo on the cover: Nu'utele (foreground) and Nu'ulua island (background) (Credit: G. Serra).

1. INTRODUCTION

Samoa is part of the Polynesia-Micronesia Biodiversity Hotspot (Fig. 1), one of 34 regions of the world where extraordinary levels of biodiversity and endemism are coupled with extremely high levels of threats (Mittermeier *et al.* 2004). Although 11 terrestrial and 65 marine species found in Samoa are listed as globally threatened on the 2015 IUCN Red List of Threatened Species, the number of threatened species at a national level may be significantly higher than this, perhaps in the hundreds (Conservation International *et al.* 2010).

Figure 1. Polynesia-Micronesia Biodiversity Hotspot (Map: Conservation International 2013).

The Aleipata islands are composed of 4 small islands with an aggregate area of 1.68 km² (see Fig. 2 and 3): Nu'utele (1.08 km²) and Nu'ulua (0.25 km²) islands located outside the coral reef off eastern Upolu; Namua (0.20 km²) and Fanuatapu (0.15 km²) islands located at the edge of the coral reef.

Known to be home of a high percentage of representative and threatened species of the whole Samoa national territory, they represent a key site within the Polynesia-Micronesia biodiversity hotspot. In a 1986 review of 226 islands in the South Pacific region, Nu'utele and Nu'ulua islands together rated 30th in importance for biological diversity (Vanderwoude *et al.* 2006). At least since a decade ago these islands have been recognized as having the potential to play a key role in sustaining the future of Samoa's fauna biodiversity.

Figure 2. The four Aleipata islands face the easternmost tip of Upolu island of Samoa. North and at the edge of the reef fringe are located the smallest islands known as Fanuatapu and Namua, the latter being the closest to Upolu and the only inhabited one of the four. To the south, well outside the reef fringe, Nu'utele, the largest island of the four and Nu'ulua the most inaccessible one (Image: Google Earth).

Figure 3. Aerial image of the four islands of the Aleipata group: foreground to the left, the Fanuatapu islet, next to the right still within the reef fringe Namua island (almost at the center of the image). In the background, Nu'ulua (small to the left) and Nu'utele (bigger to the right) (Photo: Stuart Chape).

The Aleipata islands are considered to be of great regional conservation significance because they are uninhabited (with the exception of Namua), relatively pristine as forest ecosystems, hosting many species threatened throughout the greater Samoa, and still not invaded by most invasive alien species (IAS) present within Upolu main island. Due to this reason they were included in the list of the 7 Key Biodiversity Areas of Samoa (Conservation International *et al.* 2010).

In particular Nu'utele and Nu'ulua (Fig. 4), forested volcanic islands with adjacent reef and lagoons, located 1.3 Km off the far eastern end of Upolu, are major sites for the conservation of Samoa's indigenous biodiversity. The importance of these two islands is that they are uninhabited, not easy to land by boat (therefore few IAS occurring), and large and far enough to be forested and considered as potential refuges for several of the nation's native species.

Nu'utele and Nu'ulua are customarily owned and involve at least four families that are bestowed with the traditional titles, from the villages of Satitoa and Ulutogia (part of the Aleipata District).

Due to its size and the risks and challenges in relation to landing, Nu'ulua island is only occasionally visited by locals and Government staff. No families currently use the island in any traditional way and it has most likely never been inhabited. In fact, it is the only one of the four Aleipata islands not hosting any coconut grove.

Nu'utele, due to its bigger size and being more accessible by boat (although landing is not extremely easy) has a history of use including establishing plantations and hosting a leper colony during the early 20th century (between 1916 and 1918). Currently uninhabited, it is visited by members of the family who maintain two fales at Vini beach and few crops, and bring sometimes visitors (especially academics and school groups).

The other two islands of the Aleipata group are Fanuatapu (an uninhabited islet hosting a forest of limited size) and Namua hosting a touristic resort.

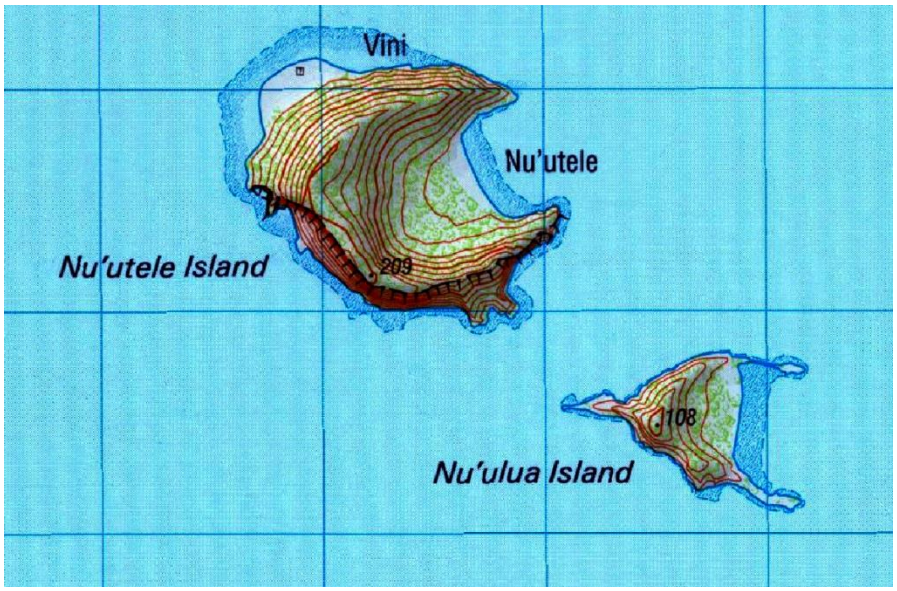


Figure 4. Topographic map of Nu'utele and Nu'ulua islands (Map: Paul Anderson/SPREP).

Due to their scarce accessibility, size and forest coverage, Nu'utele and Nu'ulua islands were selected as the target of several surveys and IAS management interventions during the past 15 years, culminated in a rat eradication attempt undertaken in August 2009.

2. AIM AND METHODOLOGY

This review is part of the requirements of a consultancy assignment, under a GEF-PAS IAS project [jointly run by MNRE/DEC and the Secretariat of the Pacific Regional Environment Program (SPREP)], aimed at assessing the present status of key IAS in the mentioned islands and at preparing a management plan. The review focuses on available reports and literature about most relevant IAS surveys and management actions undertaken in the Aleipata islands, Samoa, so far.

The review has four objectives: to review i) the current knowledge of existing biodiversity assets and threats on the mentioned islands; ii) the past and current occurrence of IAS in the islands; iii) the conservation measures in place; iv) IAS management efforts so far; v) knowledge gaps.

Relevant literature was gathered from key stakeholders and experts. Reports were examined thoroughly and further clarifications were obtained directly contacting experts involved in the past. Other key stakeholders were contacted to get insights and opinions. First draft was shared with MNRE/DEC and SPREP for comments. Following integrations of feedbacks and comments, a final version was prepared and circulated.

3. KEY BIODIVERSITY ASSETS AND THREATS

3.1 Fauna

The key fauna biodiversity assets of Nu'utele and Nu'ulua islands, holding a global relevance, can be grouped as follows:

- THREATENED TURTLE. According to MNRE/Marine Division the Critically Endangered Hawksbill Turtle *Eretmochelys imbricata* uses the beaches of these two islands as nesting sites. Reportedly the two islands support the highest number of nesting turtles in Samoa.

- THREATENED BIRDS. These two islands are among the few sites left in Samoa where the Critically Endangered and endemic Tooth-billed Pigeon *Didunculus strigirostris* can still be found. In fact, the islands offer suitable habitat for this species that is specialized in feeding on the Samoan endemic tree maota *Dysoxylum* spp. The occurrence of this bird in Nu'utele was reported last time in 2010 (Schuster 2010) - but apparently the call of this bird was also heard and detected by MNRE/DEC staff during a survey in 2013 (MNRE/DEC, *pers. comm.*). On the other hand its occurrence on this island was not recorded by surveys taken in 2005-2006 (MNRE 2006). Moreover, Nu'utele and Nu'ulua are among the two only sites in Samoa where the Friendly Ground Dove *Gallicolumba stairii*, a regionally endemic species listed as Vulnerable at global level, occurs. The two

islands actually hold the largest remaining population of this species in Samoa, a population significant in terms of the entire Western Polynesian population. The Friendly Ground Dove was the focus of a protection scheme during the rat eradication attempt carried out in 2009. Twenty six individuals were trapped and transferred to an aviary in Upolu before the eradication. The surviving twenty two individuals were released 6 weeks later. According to Alan Tye (unpublished) at least 26 were counted in 2009, after the eradication attempt, within Vini flats in Nu'utele - while David Butler estimated 92 of them in the same area in 2010. Due to the occurrence of two bird species threatened on a global scale and the presence of substantial numbers of native endemic birds and major colonies of seabirds (see below) the whole Aleipatas Marine Protected Area (see below) was enlisted as an Important Bird Area in 2010 (BirdLife, 2015).

- NATIVE ENDEMIC BIRDS. Six bird species endemic to Samoa find a haven in these islands such as the Samoan Fruit-dove *Ptilinopus fasciatus*, Samoan Whistler *Pachycephala flavifrons*, Samoan Broadbill *Myiagra albiventris*, Samoan Fantail *Rhipidura nebulosi,* Flat-billed Kingfisher *Todirhamphus recurvirostris* and Samoan Starling *Aplonis atrifusca*.

Other nationally-relevant fauna biodiversity features of the two islands are the following:

- INVERTEBRATES. The two islands in question, thanks to their uneasy boat landing, still hold good population of coconut crab *Birgus latro* that due to its size and edibility has become very rare on populated islands of Samoa. Most likely the two islands host more coconut crabs than anywhere else in Samoa. Moreover, fifteen species of land snails were collected during surveys in early 2000, 11 on Nu'utele and seven on Nu'ulua (Stinger *et al.* 2003 a and b).

- SEABIRDS. Due to the absence of resident people and their usually associated cohort of predatory tame animals (and thanks to some dramatic sheer cliffs in Nu'utele), the two islands hold the highest concentration of nesting sea birds than any other Samoa island, especially Brown Booby *Sula leucogaster*, Red-footed Booby *Sula sula*, Black Noddy *Anous minutus*, Blue Noddy *Procelsterna cerulean* and Greater Frigatebird *Fregata minor*. No burrow-nesting seabirds (petrels and shearwaters) were detected on the islands during recent surveys (Serra and Faleafaga 2015) possibly due to the presence of rats but also quite possibly due to their nocturnal and secretive habits. Apparently fishermen off the coast of Nu'utele and Nu'ulua at night hear "babies crying and people talking in the darkness".

- REPTILES. The Aleipata islands preserve ¾ of the herpetofauna of Samoa and thus unique components of the biodiversity of the islands. A total of 12 reptile species were found by Fisher *et al.* (2012), three of which are "almost endemic to Samoa". A unique assemblage of lizard species occur in these islands according to the same authors.

- MAMMALS. Two species of native bats (*Pteropus tonganus* and *Pteropus samoensis),* the latter being an endemic to Samoa and Fiji, occur in the two islands in substantial numbers. Both species are very important pollinators of forest trees.

Two surveys run in September and October 2015, under a GEF-PAS IAS project (Serra and Falefaga 2015), confirmed the occurrence of the biodiversity assets mentioned above. In particular, two possible calls of Manumea were recorded and the occurrence of Friendly Ground Dove was confirmed in both islands. Occurrence of the two species of fruit bats, of

all mentioned seabirds and native birds (with the notable exception of the Samoan Fantail) were also recorded. Three tracks of turtles were recorded on Nu'utele beach, two Hawkbill turtles were spotted on the reef in front of Vini beach, the endangered Humpback whale *Megaptera novaengliae* was observed daily around Nu'utele island (including a mother with calf), together with Spinner dolphins *Stenella longirostris*.

3.2 Flora

The two islands hold two of the few, if not unique, pristine lowland rain forest ecosystems, with almost null invasive species, still surviving in Samoa. This kind of ecosystem is threatened within the whole Pacific region. It is a quite unique ecosystem also nationally as it includes several endemic tree species. These islands support intact coastal forests, which have mostly disappeared from elsewhere in Samoa. The coastal forest of Nu'ulua is almost unique with the minimal occurrence of coconuts.

The two islands host eight plant species and two vegetation communities that are rare on the main islands of Upolu and Savai'I (Whistler 1984), known as littoral and lowland forests. Littoral vegetation is made of vines, ferns, shrubs and coconut plantations.

The uncommon and interesting species of the littoral forest are: *Thespesia populnea* (milo), *Guetarda speciosa* (puapua), *Pandanus tectorius* (fasa), *Ficus scabra* (mativao), *Tournefortia argentea* (tausuni) and *Allophyllus timoirensis*.

The flora distribution of the lowland forest vegetation along the island ridges is dominated by species such as *Syzygium clusiifolium (*asavai). Large trees like *Canarium vitiensemaali*, *Garuga floribunda* (magaui), *Cananga odorata* (mosooi), *Terminalia catappatalie* and *Inocarpus fagiferifi* are common along the eastern and western ridge slopes that are frequently visited by fruit bats. Ferns are less abundant than on Upolu: the most common are the *Asplenium nudus laugapapa* and *Phyatosorus grossus lauauta*. The *Asplenium* dominates the ground cover within Vini flats and along the western slopes.

The mentioned species is also found along the eastern slopes towards Nu'utele bay but mostly scattered and sometimes appear in large pockets. The presence of this large fern is significant as nesting place for birds like the friendly ground doves. On the summit and along the ridges the dominant species of plants are seedlings of big trees such as *Syzygium clusiifoliuma sivai*, *Diospyros samoensis*, *Diospyro selliptica*, *Planchonella garberialaa*, and *Terminalia catappatalie*.

According to Talie *et al.* (2007), the dominant tree at Vini flats is *Macaranga harveyana* (laupata) that is a common short-stature secondary tree on lowland beach areas. This is an indication of the environment disturbance caused by the two cyclones in 1990 and 1991 where the forest would have been dominated by *Terminalia catappa* (talie), *Calophyllum inophyllum* (fetau) and *Hibiscus tiliaceus* (fau).

An important information from the 2007 report is the occurrence of *Dysoxylum samoensis* (maota) that was recorded in 3 plots out of 9. Maota is an endemic tree, one of the most relevant one for pigeons and doves (the critically endangered and endemic Tooth-billed

Pigeon is specialized in feeding on this tree). Pigeons and doves carry the fruits and spread them in the forest.

Most of the vegetation is the same in the two islands, except perhaps for *Manilkara manilkara* (oani) occurring only in Nu'utele. Talie *et al.* (2007) reports no indication of negative effects on the forest of Nu'utele due to occurrence of rats and YCA. No weed species were detected nor recorded.

No information is available in the literature regarding the main threats to the biodiversity of the Aleipata islands, with the exception for the ecological invasions by alien species coming from Upolu. Based on direct experience in regards to other areas of Samoa, the other main potential threats could be the following:

- Forest logging or reclamation for plantations and crops
- Hunting, mainly of pigeons but also of other birds and bats
- Harvesting of coconut crabs.

People have never extensively farmed nor logged the islands of Nu'utele and Nu'ulua probably due to the fact that they are too small for such operations and too few profitable forest trees are present. The original ownership of these islands was under the family Sagapolu who was not interested in farming on the island.

4. INVASIVE ALIEN SPECIES

Despite growing global efforts to curtail biological invasions, the spread of invasive alien species remains an increasing conservation problem especially on oceanic islands. Boats are the key pathway for IAS introduction to Nu'utele and Nu'ulua – mostly aluminium fishing catamarans coming from Upolu.

4.1 Inventory

Fauna

1. Land snail (Gasteropoda) ***Subulina octona***, abundant in Nu'utele according to Stringer *et al.* (2000), never surveyed again since then;
2. **Yellow Crazy Ants** *Anoplolepis gracilipes* found for the first time by Smith (2003) in Nu'ulua and later by MNRE (2007) in Nu'utele; still present in both islands in September-October 2015 (Serra and Faleafaga 2015);
3. **House gecko** *Hemidactylus frenatus* (Fisher 2012), not surveyed again since then;
4. **Polynesian rat** *Rattus exulans* trapped first time in Nu'utele in 1991 (Park *et al.* 1992) and in Nu'ulua in 2004 (Parrish *et al.* 2004); still occurring in Nu'utele in September 2015 and absent from Nu'ulua in October-December 2015 (Serra and Faleafaga 2015);
5. **Pigs** *Sus scrofa* "escaped from captivity" in Nu'utele mid 2006 [Island Eradication Advisory Group (IEAG) 2006], still present in September 2015 (Serra and Faleafaga 2015).

Notable recorded absences of key IAS animals from Nu'utele and Nu'ulua that are common on Upolu were: Cockroach *Periplaneta americana*, African giant snail *Achatina fulica*, Jungle Fowl *Gallus gallus* (used to occur in Nu'utele during period 2001-2007), Common Myna

Acridotheres tristis, Jungle Myna *Acridotheres fuscus*, Red-vented Bulbul *Pycnonotus cafer* (it has been seen in 2010-11 in Nu'utele), Feral cat *Felis catus*, and dog *Canis lupus*.

It is interesting to note that the Bulbul has tried to colonize Nu'utele during the past 5-6 years (most bird species are able to cross the 1.3 Km stretch of sea separating Upolu from Nu'utele) but failed most likely because they need to associate to people in order to survive – the same as for the two species of mynas that have most likely tried the colonization of Nu'utele as well (although there is no record of this).

Flora

The vine *Merremia peltata* (fua lautetele) is present on the islands, though it is not considered seriously invasive except in disturbed areas (but these are limited in size and distribution on these two islands). The herbaceous plant *Wedelia biflora* is also present but only in open areas near beaches. A survey conducted by staff of the MNRE/DEC in 2007 found one *Albizia* tree occurring within the Vini beach area in Nu'utele (still occurring in September 2015, Serra and Faleafaga 2015).

4.2 Key species: knowledge & threats

Surveys undertaken during years 2000s identified the Polynesian rat and the YCA as the two most critical IAS threatening the biodiversity assets of the Aleipata islands. This was reflected by the Critical Ecosystem Partnership Fund (CEPF) project, a partnership between SPREP and Conservation International (CI), that was run between 2009 and 2011 (total budget ca. 220,000 USD) and that was focused mainly on the management of these two animal species (Tye 2012).

The threats to insular biodiversity produced by introduced rats are well documented (Towns *et al.* 2006, Jones *et al.* 2008). In general terms rats are a problem because they kill invertebrates, birds (especially eggs and chicks) and the seeds of native trees, preventing forest regeneration.

The Polynesian rat was probably a Polynesian introduction in the Aleipata islands or an accidental human-facilitated introduction from neighbouring Upolu in the recent past. Very little is known about the biology and ecology of this alien species in tropical islands. Rat surveys run in early 2000 showed that rats in Nu'utele have a special taste for coconut (Stinger *et al.* 2003).

This is confirmed by the fact that both in early 2000 and in September 2015 rats were found mainly among the coconut groves of the two main flats of Nu'utele (Vini and Nu'utele). The interesting fact is that rats seem not to thrive within the pristine rain forest of the slopes and the ridge of this island, consistently with results of a study about the role of *refugia* in curbing the threat of IAS in Fiji (Olson *et al.* 2006).

Many ant species that have been accidentally spread throughout the world have significant economic, environmental and social impacts in areas that they now infest. Ants in general are a problem because they attack a huge range of native plants and animals. They may destroy small seeds, attack bird nests, and kill reptiles, crabs and native insects.

One of the most notable invasive ants is the YCA. This species has a pan-tropical distribution, and is well known to have great variation in its abundance, impacts and reproductive phenology.

Field work done in the Aleipata islands showed that YCA was well distributed over the island of Nu'ulua (Vanderwoude *et al.* 2006), but is still localized to the two main disturbed areas in Nu'utele (Serra and Faleafaga 2015). The same as rats, YCA seem not to thrive within the pristine rain forest of the slopes and the ridge of this island.

The persistence of YCA on Nu'utele and Nu'ulua is of significant conservation concern. Within infested areas there were few other ants larger than YCA, as well as fewer crabs and spiders, indicating that YCA is indeed a significant conservation concern (Hoffman 2011).

YCA's spread throughout Nu'ulua is a threat to invertebrates, birds and reptiles, including turtle hatchlings, and it could lead to irreversible vegetation changes. Worker abundance and nest density were among the highest recorded in the world, being greater in May than in October (Hoffman 2011).

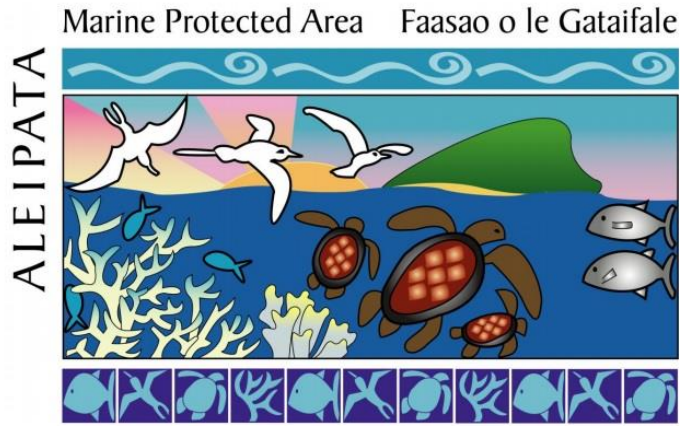
Pigs are a problem because they damage tree seedlings, dig up turtles eggs, and eat the eggs and young of ground-nesting birds. They are still occurring and breeding in Nu'utele (Serra and Faleafaga 2015), despite reiterated recommendations to eradicate them have been issued as early as 2006 (IEAG 2006).

4. CONSERVATION MEASURES

In 1989 the International Union for Conservation of Nature (IUCN) prompted the establishment of a marine protected area (MPA) including the four Aleipata islands (Fig. 5).

Figure 5. Aleipata marine protected area (MPA). Legend: area shaded in blue: lagoon; area shaded in brown: coral reef; area shaded in purple: reef slope; areas shaded in white: insular terrestrial ecosystems. Map: Conservation International *et al.* (2010).

The government in collaboration with the Aleipata District (eleven villages in total) and IUCN developed a management plan, the last update being for the period 2008-2010 (MNRE 2008), with the aim to guide the protection and conservation of the marine environment of the Aleipata District.



The four Aleipata islands are integrant part of the MPA. In fact, one of the guiding principles of the Aleipata MPA's management plan states that "We commit Aleipata's offshore islands (Nuulua, Nuutele) and their wealth of biodiversity as a critical part of our Aleipata MPA". The same plan acknowledges that "Aleipata's islands are vitally important refuges for Samoa's natural heritage and

we will continue to support these islands as an integral part of our Aleipata MPA. These islands are also a vital part of our history and culture and we will also ensure conservation of the cultural heritage they contain".

As the project progressed, the MPA Committee composed by eleven mayors, decided to bring in the support of Conservation International (CI) in order to strengthen the partnership and ensure availability of funding. A trust fund was established in 2003 by CI aimed at the implementation of the management plan. Few locally managed no-take zones were established and run for some time. CI in collaboration with CEPF and SPREP became keen to implement the part of the management plan focusing on Nu'ulua and Nu'utele islands (priority working goal # 3.3). Thus project mentioned in point 4.2 was funded and implemented.

A large shipyard with dry dock was established by the Government in the middle of the MPA during the 1990s and started its operation of ship renovations despite the advise of CI and of an environmental impact assessment. The MPA operation came to an halt soon after the tsunami of September 2009, due to problems in managing the trust fund and amidst allegations of corruption. Investigations are apparently still under way. The management plan was never updated beyond 2010. Apparently there are intentions to revive and update it during 2016 (MNRE/Marine Division *pers. comm.*).

In fact, during recent survey run between September and December 2015 (Serra and Faleafaga 2015), and during other informal visits in previous years, no apparent indications were observed on the ground that an operational marine protected area is in place in the area (e.g. no signs, no information panels for visitors, no enforcement noted).

A biosecurity training was conducted in 2009 by the Pacific Invasives Initiative (PII) as part of the mentioned CEPF project in the benefit of local communities, government staff and MPA committee members. The training was unfortunately interrupted by the tsunami. A draft biosecurity manual and visitor checklist was prepared but never printed (as it had been planned).

According to Butler *et al.* (2011) and Tye (2012) no biosecurity has ever been established following the CEPF project. This was confirmed by the recent two surveys of the four Aleipata islands by Serra and Faleafaga (2015).

5. ATTEMPTS OF MANAGING IAS

The CEPF project was conceived as the direct implementation of priority working goal #5.3.1 of the Aleipata MPA management plan ("a key step towards a long-term goal of ecological restoration and maintenance of Nu'utele and Nu'ulua islands"). The project was designed to address the threats to the rain forest ecosystems of the two islands posed by two key invasive alien species: the Polynesian rat and the YCA (SPREP 2008).

It was designed as a demonstration project with the PII and with the Pacific Invasives Learning Network facilitating the involvement of others from the region in the operation and the wide dissemination of its results.

As a step towards island restoration, the project aimed to eradicate Polynesian rat from both islands through aerial delivery of baits from a helicopter. The project originally also proposed to control or eradicate YCA by ground and aerial delivery of baits but, following expert advice, this objective was changed to obtain further information considered necessary for the design of a long-term management plan.

The local people who own and use the islands gave their support to the rat eradication as part of the Aleipata MPA project. The project thus involved working very closely with the community, through an MPA Committee involving representatives of all the villages in the District. Community members joined expeditions to the islands, were involved in the control operations and were invited to play a key role in preventing pests from reaching the islands.

SPREP signed a grant agreement with the CEPF on 1 May 2009 to deliver this project, with seven components:

1. Eradication of Polynesian rat using aerial delivery of poison
2. Protection of Friendly Ground Dove from the poisoning operation
3. Management of YCA
4. Monitoring the response of the ecosystem to rat removal
5. Work with the local community to maintain support for the project and raise awareness of the need to protect the islands
6. Establishment of a biosecurity programme for the islands
7. Dissemination of results.

The full final report (Tye 2012), including detailed outcomes and lessons learned, is available online: https://www.sprep.org/publications/restoration-of-nuutele-and-nuulua-islands-aleipata-group-samoa-through-the-management-of-introduced-rats-and-ants

Rat eradication attempt

Rat eradication of Nu'utele and Nu'ulua was one of the first helicopter-delivered rat eradication attempts on islands of Oceania, and surely the first attempted in Polynesia.

The eradication operation carried out at Nu'utele during the second half of August 2009, through 3 subsequent aerial spreading of rat toxin (brodifacoum), unfortunately did not succeed, as shown by several rat surveys undertaken during following years (Butler 2011a and b; Serra and Faleafaga 2015). On the other hand, based on several rat surveys run between 2009 and 2015 (Fisher *et al.* 2012; MNRE 2012; Serra and Faleafaga 2015), it seems now clear that the eradication attempt in Nu'ulua was successful.

The reasons of the failure of rat eradicaion in Nu'utele unfortunately will never be known: rat tail samples collected for DNA analysis (pre-treatment and post treatment ones) were lost within New Zealand in 2011 while transiting internally via a courier package.

Recently the feasibility of a late DNA analysis based on the comparison of current rat samples from Aleipata islands *versus* those from Upolu (in the irreversible absence of the pre-treatment samples from the islands) was excluded by Dr Rachel Fewster from the

Department of Statistics of the University of Auckland (email communication exchange posted in Annex 1).

Therefore only hypothesis can be mentioned in relation to the eradication failure of Nu'utele island. Below table is an attempt to list all the most likely proxy and root causes of the failure that were found mentioned in the available reports and literature.

Proxy causes	***Reference***
Coverage of ground with toxin dropped by helicopter was not complete due to: i) technical problems with the spreader bucket and with the GPS devices; ii) pilot inexperience; iii) occurrence of rain soon after the spreading.	IEAG (2006), Wylie (2009), Butler *et al.* (2011)
Incorrect lapse between drops ("11 dd lapsed between the first and the second drop, while Alan Saunders had advised at least 14 dd").	Watkin (2012)
Challenges with weather forecasts: forecasts of limited reliability, intrinsic unpredictability of rainfall in the tropics. E.g. 6.25 mm of rain fell during the first night following the first drop; 2009 dry season turned out to be wetter than usual due to El Ninho.	Wylie (2009), Butler *et al.* (2011), Tye (2012)
Rats on Nu'utele have plenty of food all year round (coconuts), recent evidence collected that they breed also during the dry season (second half of August, i.e. same timing of treatment in 2009); unclear (to be tested) whether all rats would prefer the toxic bait to their abundant natural food.	Keitt *et al.* (2014); Serra and Faleafaga (2015) Ulf Beichle (*pers. comm.*)
Possible re-invasion of rats via the tsunami that took place in September 2009, only few weeks after the eradication.	Butler *et al.* (2011), Tye (2012)
Biosecurity measures not applied thoroughly, neither before nor after the eradication attempt.	Butler *et al.* (2011), Tye (2012)
Root causes	***Reference***
Late confirmation of funding from the donor (project approved on 27 April 2009, funds received on 2 June 2009, first drop scheduled for early August 2009) which implicated tight timeframes: for instance, technical recommendations from IEAG/DOC (2006) such as the use of two buckets, two DGPS and a test of equipment before the operation could not be applied.	IEAG (2009), Wylie (2009), Butler *et al.* 2011, CI (2013)
Capacity loss due to staff turnover at MNRE (three changes to the project manager within MNRE during the ten weeks before the first drop); challenges with MNRE support.	Butler *et al.* 2011, Tye (2012), CI (2013)
Management issues: unclear roles, insufficient focus and time of some roles, SPREP part-time management, "problematic project management structure", 5 people responsible for managing MNRE's	IEAG (2009), Butler *et al.* 2011

inputs to the project etc.: all this translated into challenges in maintaining project momentum and ensure tasks were completed on schedule.	
Some level of disconnect between the respective roles of the project including SPREP, MNRE and the local communities.	Watkin (2012)
Risks associated with rat eradication at tropical latitudes (*versus* those at temperate latitudes, e.g. in NZ) were not emphasized sufficiently with stakeholders and the donor prior to the operation; expectations were possibly unrealistically too high.	Keitt *et al.* (2014)
Biosecurity not in place at the time of eradication despite IEAG/DOC had clearly recommended it to be "in place and functioning well before pests are removed" (recommended twice, once in 2006 and then in 2009, "urgently"); recommended also by Wylie 2009.	IEAG (2006, 2009), Wylie (2009), CI (2013)
Possible insufficient biological and ecological knowledge about Polynesian rats occurring in Samoa/Aleipata islands.	Ulf Beichle (*pers. comm*); Keitt *et al.* (2014)

Despite the rats were found on Nu'utele following the eradication attempt, the project apparently resulted in a release of forest regeneration and of populations of some animals, and the long-term effects of this was to be positive for the island ecosystem (Butler *et al.* 2011, Tye 2012).

MNRE accepted to include follow-up activities for some components of this project in its workplan financed under the GEF-funded PAS IAS project, namely further monitoring of rats and further investigation on YCA's biology and ecology.

YCA surveys

YCA surveys led by Dr Ben Hoffman on Nu'utele in October 2010 and March 2011 (Hoffman 2011) revealed insights on the distribution and expansion since the previous time they were surveyed in 2006, on the reproductive phenology, on the annual cycle of abundance and on the annual nest density cycle. Impact on co-existing fauna was also assessed together with interactions with phytophagus insects and extrafloral nectar.

Part of the study on YCA (the monthly ant monitoring) was planned to be carried out by MNRE staff, but this never materialized. The conclusion from data analysis was that before a management plan is written and implemented, further and improved knowledge is required about suitable bait-toxin mixes, on side-effects to native fauna and especially on ant breeding cycle in the Aleipata islands and in Samoa.

Following the recommendations made by Ben Hoffman to undertake targeted research on YCA in Aleipata islands/Samoa, the GEF-PAS IAS project (Samoa component) included an activity termed "research on YCA in Aleipatas" with an allocation of 20,000 USD. This activity however was recently revised by the Samoa National Invasives Technical Team and turned into a more general one: review of past IAS management efforts (as an outcome the present

review document), new IAS surveys in the Aleipata islands and preparation of a IAS management plan for the Aleipata islands.

Pigs

IEAG (2006 and 2009), in addition to other experts, strongly recommended feral pigs to be removed from Nu'utele as a matter of priority. A pig shooting exercise was carried out in 2007 according to Talie *et al.* (2007). But pigs are still present and breeding in Nu'utele as recently documented by Serra and Faleafaga (2015). The damage to native biodiversity and the rain forest ecosystem during period 2009-2015 can be estimated as substantial. Their removal is a relatively easy task – certainly it is compared to removing rats and YCA. The mere fact that this has not happened so far may be an indication of lack of awareness about the threat of IAS on part of competent authorities and local communities.

Biosecurity

The CEPF project planning phase evaluated the probabilities of rats reaching the islands by various means, and considered that they were low enough to recommend eradication, but that improving biosecurity was advised. The occurrence of a tsunami soon after the eradication attempt was not taken into account as a likely event to occur – and yet it happened right few weeks after the eradication attempt, ironically during the undertaking of the biosecurity training held in New Zealand.

The project included a set of activities to improve biosecurity for the islands. MNRE staff and the local communities of Aleipata District were trained in biosecurity and given the means to implement improved measures. This included training, the development, production and use of biosecurity protocols and guides, and the implementation of a long-term monitoring and rapid response system.

The biosecurity training led by PII was scheduled for September 2009 in Auckland, and local community representatives and MNRE members were attending the course when the tsunami struck Samoa. The Samoan participants had to abandon the course and return to their families, and this workshop was eventually completed in Samoa in March 2010. A biosecurity manual and visitors' guide (MNRE & Aleipata Islands MPA Committee 2012, MNRE *et al.* 2012) were developed by SPREP and PII, and submitted to MNRE for publication and distribution.

A system to inspect boats, equipment and supplies taken by people visiting the islands was established by the MPA Committee and they undertook inspections through most of 2010. However, the system lapsed in 2011. Lines of bait stations with wax baits and traps were set up on Vini Beach in January 2010 and on Nu'utele Beach in March 2010. Such devices have not yet been set up on Nu'ulua owing to problems of access.

Nu'ulua can only be reached if seas are relatively calm and the consequent low rate of visitation by boats is one of its key defences against re-invasion by rats. It has not been possible for MNRE to establish regular monitoring or a rapid-response system for the islands. This should be a major concern for any future eradication plans, whether of rats or any other pest on the islands.

According to Tye (2012), “the community-managed biosecurity system for the islands was not maintained. Biosecurity is no better than before the project, and further pest incursions to the islands may be expected. A monitoring and rapid-response system, to be operated by MNRE, has not been established.” Serra and Faleafaga (2015) confirmed the absence of any biosecurity measure in place in relation to the four Aleipata islands.

A Samoa Invasive Species Emergency Response Plan (SISERP) was prepared in 2015 under the GEF-PAS IAS project. This document defines the guidelines for an emergency response to the threat of a new potential invasive species at a national level.

Additional remarks

The main challenges to sustainability of CEPF project were the inconsistent support provided by government and local community partners to different aspects of the project (Tye 2012). However, the project clearly fell within the priorities of Samoa’s National Invasive Species Action Plan (NISAP), and follow-up activities have been included by MNRE in its plans under the GEF-PAS Invasive Species project which began in 2012, including further monitoring on the islands and revision of Samoa’s Emergency Response Plan to cover incursions more effectively.

The final report of the CEPF project (Tye 2012) recommended the following:

- Rat survey in Nu’ulua (plan included in the GEF-PAS IAS project)
- DNA analysis to get conclusion on new rat management plan (plan included in the GEF-PAS IAS project)
- Pigs and fowl eradication (assumed to be led by MNRE and local communities with zero investment as these are edible animals)
- Monitoring Friendly Ground Doves and other birds, together with vegetation, reptiles and invertebrates
- YCA research (recommended by Dr Hoffman, originally included in the GEF-PAS IAS project)
- MNRE continues to work closely with the MPA Committee and Aleipata District communities, to ensure the maintenance and enhancement of the biodiversity values of the islands
- The community-managed biosecurity system is provided continuous support from MNRE if it is to become and remain functional
- Publication of the biosecurity manual for Aleipata islands and the visitos’ checklist (not done so far)
- The biosecurity guidelines included in the biosecurity manual should also be adhered to and enforced by MNRE
- A long-term surveillance programme is established on Nu’ulua and Nu’utele, to detect new pest incursions and a rapid-response system needs to be developed to deal with incursions detected (outline plans for these being included in the biosecurity manual).

6. IDENTIFICATION OF KNOWLEDGE GAPS

Lack of biological and ecological knowledge of IAS is recognized as a major factor contributing to eradication failures. Management must be informed by a site-specific understanding of the invasion system.

Polynesian rats are known to survive well on remote Pacific islands making the best out of what is available, and especially foraging on coconuts. In order to increase the chances of success of any future second rat eradication attempt in Nu'utele, it would seem sensible trying to improve the knowledge about the distribution, the breeding cycle and the diet of the rats on that island thoroughly during the course of 12 months at least.

Particularly, it seems crucial to get a better understanding of whether there is any annual low point of productivity on these islands or not. Also the issue of bait palatability at tropical latitudes and how to best address the challenge of the unpredictability of rainfall events should be investigated further.

Although there have been many attempts at eradicating exotic ant incursions, few efforts have been successful, and a lack of specific biological and ecological knowledge is believed to have been a major contributing factor.

In situ knowledge of the biology and ecology of a species is vital to create effective management protocols. This is particularly important for YCA because globally there is great variation in its abundance, impacts and seasonal phenology, and its reproductive strategy is particularly problematic and unresolved (Drescher et al. 2007; Gruber *et al., in press*).

Due to this, during CEPF project, leading researcher Dr Ben Hoffman recommended to not attempt any action of control and eradication of YCA until some key knowledge gaps are addressed.

Targeted site-specific research was recommended. Investigation of the yearly breeding cycle in Samoa and the side-effects of treatment on other species (especially crabs) were indicated as priority gaps of knowledge to be filled.

The timing of male reproduction appears to be consistent with places elsewhere in the world, but queen reproduction was found to be outside of the known reproductive period for this species in the region, indicating that the timing of treatment regimes used elsewhere are not appropriate for Samoa.

For example, baiting during periods when queen brood are in pupal stage will not achieve eradication because these pupae will not be affected by the treatments and will emerge to initiate new colonies. A lack of site-specific information can also hinder effective assessment of treatment success (Hoffman 2012).

6. ACKNOWLEDGEMENTS

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APPENDIX 1

ENQUIRING ON THE FEASIBILITY OF A LATE DNA ANALYSIS

-----Messaggio originale-----
Da: Rachel Fewster [mailto:r.fewster@auckland.ac.nz]
Inviato: Thursday, 17 September 2015 11:37 p.m.
A: g. serra
Cc: faleafaga tipamaa; maturo.paniani@mnre.gov.ws; Rachel Fewster
Oggetto: RE: DNA analysis rat samples Aleipatas islands, Samoa

Dear Gianluca,
Can I just confirm a few details: you're trying to find the source of rats that have been on the Aleipata Islands since 2009, specifically whether they are descended from the pre-eradication rats or whether they are migrants from the main island Upolu. You can collect contemporary samples from Aleipata Islands and from Upolu, but you won't have any samples from pre-eradication Aleipata Islands, in other words the "survivor" population?

Which species of rat is it?

If I've got this right, I'm a bit concerned that you might not be able to address the question adequately without having the pre-eradication Aleipata Islands samples. The problem is that the pre-eradication Aleipata Islands would quite likely have been a genetic subset of the Upolu rats. If so, then we can only really distinguish rats in one direction: we'd be able to say that a Upolu rat couldn't have come from the pre-eradication Aleipata Islands (because it has genes that have been lost from the Aleipata Islands), but we wouldn't be able to say that an Aleipata Islands rat couldn't have come from Upolu because all its genes are there available on Upolu.

This would mean that any present day rat on the Aleipata Islands could genetically have come from Upolu, regardless of whether it is descended from Aleipata Islands survivors or whether it came over from Upolu after the eradication. So you could go to a lot of expense and not really get any answer from the results.

The only situation where you would get a result is if the pre-eradication Aleipata Islands rats were very different from Upolu, for example if they had originated from a different source when the islands were first colonised. Additionally, you would also need that the truth was a failed eradication and that the present-day rats are survivors from this very different population. Then we could tell genetically that the present-day rats are very different from the Upolu rats and we could deduce that the only explanation is if the pre-eradication Aleipata Islands rats were also different from Upolu, and this would imply that the present-day rats are descendants of these rats, in other words survivors.

However I think this scenario is rather unlikely, unfortunately. It's more likely that Upolu and Aleipata Islands were genetically similar before the eradication, and that we would need the pre-eradication samples to be able to distinguish the source of the present-day rats. I am a bit worried that the genetic analysis won't be worth the money it will cost, assuming that I've got it right that there aren't any pre-eradication samples available.

To answer your specific questions:

- Samples of size 30 from every source population are ideal: for example from Upolu and from pre-eradication Aleipata Islands. It doesn't matter how many samples you get from post-eradication Aleipata Islands if the aim is to say whether these rats could, or could not, be drawn from Upolu. We'd treat every post-eradication rat as a separate analysis. But if you do want to go ahead regardless of the problems above, I'd suggest you should try to get at least 15 rats from Aleipata Islands and preferably a few more.

- 70-90% ethanol is ideal for preparation. It's best if you can keep the samples in the fridge after preserving in ethanol. The other thing to note is not to stuff too much tail into a single bottle. Only a tiny amount of tail (2-4cm) is needed for genetic analysis. It's much more important that there is enough ethanol to permeate the tail tissue completely, so it's better to use a smaller amount of tail and not overfill the bottles.

- We now send all rat samples to EcoGene for processing: they are a commercial lab and their current prices are (I think) about $100 NZ per rat: I'll look out the correct pricing and let you know. So it isn't cheap: it would be maybe $5000 NZ to process the samples you need for a good analysis. I'd just suggest that you weigh up this expense against the other objectives of the project and consider whether the funds might be better spent elsewhere in this particular situation.

Of course it would be good to sample the the Aleipata Islands population now if there is a plan to eradicate it again and you want to store samples for a future DNA analysis in case of a future invasion. It's the pre-eradication samples that are the all-important ones, unfortunately. Anything else can be dealt with at a later date, but you can only take the pre-erad samples while the population is still extant.

I hope this is helpful. I'll look out those prices now.

Best wishes,
Rachel

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From: g. serra [abunug@gianlucaserra.com]
Sent: Thursday, 17 September 2015 2:48 p.m.
To: Rachel Fewster
Cc: faleafaga tipamaa; maturo.paniani@mnre.gov.ws
Subject: DNA analysis rat samples Aleipatas islands, Samoa

Hello Rachel, I have just been given your contact by Bill Nagle.

[…]

Among several other tasks a very important one would be to get sufficient rat tail samples in order to try to understand the reason for the failure of the eradication attempt that was run in 2009 (CEPF project).

As you may recall, all the samples collected at that time (pre-treatment tails, post-treatment tails and main island/Upolu tails) were mysteriously lost between Nelson and Auckland. So that critical DNA analysis could never be run.

Could you kindly give us the contact of somebody from Auckland University that you consider would be keen to run this new DNA analysis?

Most likely we will start the survey next Monday (sorry for the short notice, I have been struggling to find your contact).

In particular, we would like to get instructions on the sample size needed in order to make a meaningful DNA analysis. We assume we will collect as many samples as possible from the Aleipatas and then others from the main island of Upolu.

We were told to use ethanol 70-90% in order to store these samples: kindly confirm this is correct.

I would greatly appreciate your feedback on this matter.

Thank you very much.

Best regards (also from Bill)

Gianluca