RAPID BIODIVERSITY ASSESSMENT OF UPLAND SAVAI'I, SAMOA

JAMES ATHERTON AND BRUCE JEFFERIES (EDITORS)

DECEMBER 2012

FA'AVAE I LE ATUA SAMOA
MNRE

CRITICAL ECOSYSTEM
PARTNERSHIP FUND

SPREP
Secretariat of the Pacific Regional Environment Programme

SPREP Library/IRC Cataloguing-in-Publication Data

Secretariat of the Pacific Regional Environment Programme (SPREP)

Atherton, James and Jefferies, Bruce (editors)

Rapid biodiversity asssessment of upland Savai'i, Samoa / by James Atherton and Bruce Jefferies (editors) – Apia, Samoa : SPREP, 2012.

176 p. 29 cm.

ISBN: 978-982-04-0470-0 (print)
978-982-04-0469-4 (online)

1.Biodiversity – Samoa – Savai'i. 2. Biodiversity conservation - Samoa - Savai'i. 3. Ecosystem management – Samoa – Savai'i. I. Ministry of Natural Resources and Environment (MNRE). II. Pacific Regional Environment Programme (SPREP). III. Title.

333.95099614

Cover photos:
Background: The pristine forests of Upland Savai'i from helicopter (photo by J. Atherton).
Bottom left: The endemic Samoan Skink (*Emoia samoensis*) (photo by C. Brown).
Bottom middle: The Red-headed (Samoan) Parrotfinch (*Erythrura cyaneovirens*) (photo by R. Stirnemann).
Bottom right: the endemic moth *Monosyntaxis samoensis* (photo by E.Edwards).

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The Pacific environment, sustaining our livelihoods and natural heritage in harmony with our cultures.

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The Critical Ecosystem Partnership Fund is a joint initiative of l'Agence Française de Développement, Conservation International, the European Union, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation.


Photo: Stuart Chape.

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MNRE

The Ministry of Natural Resources and Environment focuses on developing regulatory frameworks for sustainable management of the Samoan environment and its natural resources along with the implementation of projects at the local and national levels that promote improved quality of life for all. The Ministry has six main goals within its organisational framework including policy development, resource management, programme planning, scientific and technological information, along with effective implementation of projects at all levels. The involvement of the Ministry in this Savai'i BIORAP indicates its strong support and commitment to preserve and protect the biodiversity of Samoa in order to maintain Samoan culture and natural heritage.

For more information visit: http://www.mnre.gov.ws/

SECRETARIAT OF THE PACIFIC REGIONAL ENVIRONMENT PROGRAMME (SPREP)

The Secretariat of the Pacific Regional Environment Programme (SPREP) has been charged by the governments and administrations of the Pacific region with the protection and sustainable development of the region's environment. SPREP is based in Apia, Samoa, with over 70 staff.

SPREP's activities are guided by its Strategic Action Plan 2011–2015, which was developed through extensive consultations with Members, Secretariat programme staff and partner organisations. The Plan establishes four strategic priorities, which form the basis and focus of SPREP's work: Climate Change; Biodiversity and Ecosystem Management; Waste Management and Pollution Control; and Environmental Monitoring and Governance. SPREP is actively engaged as a partner in many environmental management and conservation projects in the region such as this biodiversity assessment of Upland Savai'i.

For more information visit: http://www.sprep.org/

CRITICAL ECOSYSTEM PARTNERSHIP FUND (CEPF)

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For more information visit: http://www.cepf.net

CONSERVATION INTERNATIONAL PACIFIC ISLANDS PROGRAM

The focus of Conservation International's Pacific Islands Program is to provide for the development of sustainable societies by the people of the Pacific Islands, through the preservation of natural capital and adaptation to climate change. CI's Pacific Islands Program covers 20 – 30,000 islands in the 22 countries and territories which make up the Polynesia-Micronesia and New Caledonia Biodiversity Hotspots, and Papua New Guinea. The total oceanic coverage of the program is around 40 million sq km (more than four times the size of the continental United States). The Pacific Islands Program is the only regional program within CI's Asia-Pacific Field Division. It consists of three sub-country/territory programs with linked national strategies for Fiji, Papua New Guinea and New Caledonia, and a regional Pacific Oceanscape field program.

For more information visit http://www.conservation.org/Pages/default.aspx

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BirdLife International is a global network of 117 national NGOs (Partners) – including seven in the Pacific – whose mission is "to conserve wild birds, their habitats and global biodiversity, working with people towards sustainability in the use of natural resources".

The BirdLife Partnership is supported by a Secretariat with headquarters in Cambridge, UK. A regional supporting Secretariat for the Pacific Partnership is based in Fiji, and includes a 'BirdLife Fiji Programme' pending the admission to the Partnership of an eligible Partner NGO there. BirdLife's Pacific Partners are in Australia, Cook Islands, French Polynesia, New Caledonia, New Zealand, Palau and Samoa with a country programme managed by the Pacific Secretariat in Fiji.

For more information visit: http://www.birdlife.org

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Preventing Extinctions

Island Conservation works internationally to prevent extinctions by removing invasive species from islands. Islands are where the concentration of both biodiversity and species extinction is greatest, and by removing one of the greatest threats, introduced invasive vertebrates, lasting protection can be obtained for many globally endangered species. Island Conservation began as a network of conservationists in 1994 and became a charitable organization in 1997. Working together with local communities, government management agencies and conservation organizations, we select islands that have the greatest potential for preventing the extinction of globally threatened species; develop comprehensive plans for the removal of invasive species; implement the removal of invasive species; and conduct research to understand the ecosystem changes and benefits to inform future conservation action.

For more information visit:
http://www.islandconservation.org

NEW ZEALAND DEPARTMENT OF CONSERVATION (DOC)

The New Zealand Department of Conservation works nationally conserving natural and historic heritage and recreational opportunities on public conservation lands including national parks, world heritage areas, much mountain land and many islands along with some marine protected areas. The department has an official role advocating protection of wildlife including for example birds, freshwater and marine life. Active Maori relationships with natural heritage are respected under the principles of the Treaty of Waitangi. The Department partners many agencies and organisations in its work and provides some capacity to cooperate internationally in work such as pest eradication from islands and technical support for conservation management such as this BIORAP.

For more information visit: http://www.doc.govt.nz/

UNITED STATES GEOLOGICAL SURVEY (USGS)

The United States Geological Survey (USGS) is a science organization that provides impartial information on the health of our ecosystems and environment, the natural hazards that threaten us, the natural resources we rely on, the impacts of climate and land-use change, and the core science systems that help us provide timely, relevant, and useable information.

As the United States' largest water, earth, and biological science and civilian mapping agency, the USGS collects, monitors, analyses, and provides scientific understanding about natural resource conditions, issues, and problems. The diversity of our scientific expertise enables us to carry out large-scale, multi-disciplinary investigations and provide impartial scientific information to resource managers, planners, and other customers at home and overseas.

For more information visit: http://www.usgs.gov/

Acknowledgements

This Biological Rapid Assessment Programme (BIORAP) survey of Upland Savai'i would not have been possible without the help and assistance of many individuals and organizations. First and foremost we thank the communities of Savai'i for giving permission for the survey to be conducted on village lands and for being wise stewards of their natural resources. In particular we thank the A'opo Pulenuu Pa'o Lilia for facilitating access to A'opo lands. We thank the Critical Ecosystem Partnership Fund (CEPF) and the Conservation International Pacific Islands Program for providing the funds to enable this BIORAP survey to be conducted.

This project was designed and implemented by staff of the Secretariat of the Pacific Regional Environment Programme (SPREP) and the Ministry of Natural Resources and Environment (MNRE) of the Government of Samoa. Key logistical personnel were Bruce Jefferies, Paul Anderson and Easter Galuvao (SPREP), James Atherton (consultant), and Suemalo Talie Foliga and So'oalo Tito Alatimu (MNRE). We thank the following organizations for providing personnel for the RAP survey: the Ministry of Natural Resources of the Government of Samoa, the Department of Conservation (NZ), the Conservation International Pacific Islands Program, Island Conservation, the Birdlife Pacific Partnership, and the US Geological Survey. We thank the New Zealand High Commission and the New Zealand Defence Force for helicopter transport on Savai'i, the Asia-Pacific Technical College for providing and installing our mess tent, Blue Bird Lumber and Hardware for logistical support and the Samoa Airport Authority for giving us access to helicopter landing sites on Savai'i.

The Savai'i BIORAP was a success due to the outstanding contribution of the following individuals most of whom are affiliated to the above mentioned institutions: Arthur Whistler, David Butler, Faleafaga Toni Tipamaa, Taupau Maturo Paniani, Vilikesa Masibalavu, Sue Mulvany, Martha Suter, Eric Edwards, Siamau Ualesi, Vaetoe Meki Tauai, Warren Chinn, Frank Fidow, Kirsty Swinnerton, Fred Brook, Elisala Ilaoa, Finau Masoe, Afano Lologa, Vailega Timoteo Moresi, Fialelei Enoka, Robert Fisher, Rebecca Harris, Mark O'Brien, Rebecca Stirnemann, Rudy Bartley, Taavale Masoe, Folasia Esau Faatafa, Mailata Iosia Leau and Moeumu Uili. We thank Dr Greg Sherley and John Dugdale for reviewing chapters of this report and providing many useful comments.

We would also like to express our gratitude to our local field guides, trail cutters and porters for their indispensable help and enthusiasm throughout the survey. E fa'afetaia i latou uma ua taua i luga ona o la latou lagolago ma le fesoasoani i lenei galuega.

Foreword

This report presents the results of a rapid biodiversity assessment survey (BIORAP) carried out in the upland cloud forests of the Samoan island of Savaii, the largest contiguous area of tropical forest in Polynesia. Savaii lies within the Polynesia-Micronesia Biodiversity Hotspot and includes all the islands of Micronesia, Polynesia and Fiji. The purpose of the BIORAP was to improve the state of knowledge of this important area and to provide a basis for the conservation and management of nationally, regionally and globally important ecosystems, biodiversity and threatened species. A particular focus of the survey was to gain a better understanding of Samoa's endemic, rare and endangered plants and animals.

This successful implementation of the BIORAP was made possible through the partnership between the Ministry of Natural Resources and Environment and SPREP. Funding was provided through a grant from the Critical Ecosystems Partnership Fund (CEPF), a funding collaboration that includes Conservation International, the French Development Agency, the Global Environment Facility, the Government of Japan, the John D. and Catherine T. MacArthur Foundation, and the World Bank. A key component of the BIORAP that needs special recognition was the partnership established with local land-owning communities, in particular the village of Aopo, which claims ownership of much of the area the survey. The New Zealand Ministry of Defence - Royal New Zealand Air Force No. 3 Squadron provided helicopters that contributed significantly to the survey. Without this logistical support from RNZAF, the actual survey would have been very difficult to organize. These partnerships enabled a team of more than 19 specialists from; Isle Botanica, David Butler Associates Ltd, NZ Department of Conservation, Samoa Ministry of Natural Resources and Environment, Island Conservation, BirdLife International Pacific Programme, Massey University, U. S. Geological Survey, Conservation International working alongside civil society participants including customary resource owners, to successfully complete the survey on the cloud forests of central Savaii.

Now the challenge is to ensure that the outcomes and recommendations of the survey are translated into positive on-the-ground action. Several recommendations in this report emphasize the status and importance of customary land tenure, and note that customary resource owners have stewardship responsibilities that are wider than immediate families and communities. Advocacy and outreach activities that recognise this fundamental reality will not be easy to formulate or implement. We do, however, strongly believe that this is a key element for future activities, which will need serious commitment and one which has been taken seriously by the Ministry through other relevant interventions and funding.

This report provides a useful and pragmatic series of conclusions and recommendations. Collectively these provide useful guidelines for the development of follow-up activities and inform national planning processes such as the National Environment Sector Plan and the review of Samoa's National Biodiversity Strategy and Action Plan. The BIORAP survey and its key findings have confirmed the extremely high biodiversity and ecosystem values of the uplands and cloud forests of Savaii.

The recent attention that the Samoan Tourism Authority (STA) is placing on the Savaii uplands is another clear indication that, as well as biodiversity significance, this area has economic importance particularly in terms of offering outstanding tourism experiences. Integrating tourism into protected area management is a continuous challenge. There are, however, many excellent regional examples that can be drawn upon to provide guidance for the tourism industry, communities and resource management agencies.

We commend all of the individuals and organisations that collaborated to carry out the field survey work (often under very difficult physical conditions) and who contributed to this report.

SPREP and MNRE are committed to continue to work together to ensure this area of national, regional and global conservation significance is well managed and protected.

Taule'ale'ausumai Laavasa Malua

Chief Executive Officer
Ministry of Natural Resources and Environment

David Sheppard

Director-General
Secretariat for the Pacific Regional Environment Programme

Executive Summary

This BIORAP (Biological Rapid Assessment Program) survey was undertaken as part of the process to facilitate improved management of the forests and biodiversity of Upland Savai'i. More specifically, the survey was conducted to fill key gaps in the knowledge of this globally important put poorly studied region of montane and cloud forests. This information will be used to make better informed decisions on the conservation management of the biodiversity in the area in conjunction with Savai'i land-owning communities, relevant government departments and other partners.

The Savai'i BIORAP was carried out in the upland (above 1,000m) region of Savai'i, Samoa, by a multidisciplinary and multinational team of experts from 20 to 31 May 2012. The upper slopes of the 1,860m-high island of Savai'i are covered with a dense, relatively undisturbed rainforest, which accounts for the island's 23rd place in a ranking of the conservation value of South Pacific islands (Dahl 1986). When combined with the montane and lowland rainforest below it, the area probably comprises (with the possible exception of the Big Island of Hawai'i) the largest intact block of tropical rainforest in Polynesia, more than 700km^2 in area (CI, MNRE and SPREP 2010). The upland forests are considered a priority for the expansion of Samoa's conservation area network because of their large area and natural condition and because they capture many of the threatened terrestrial species in the country (ibid).

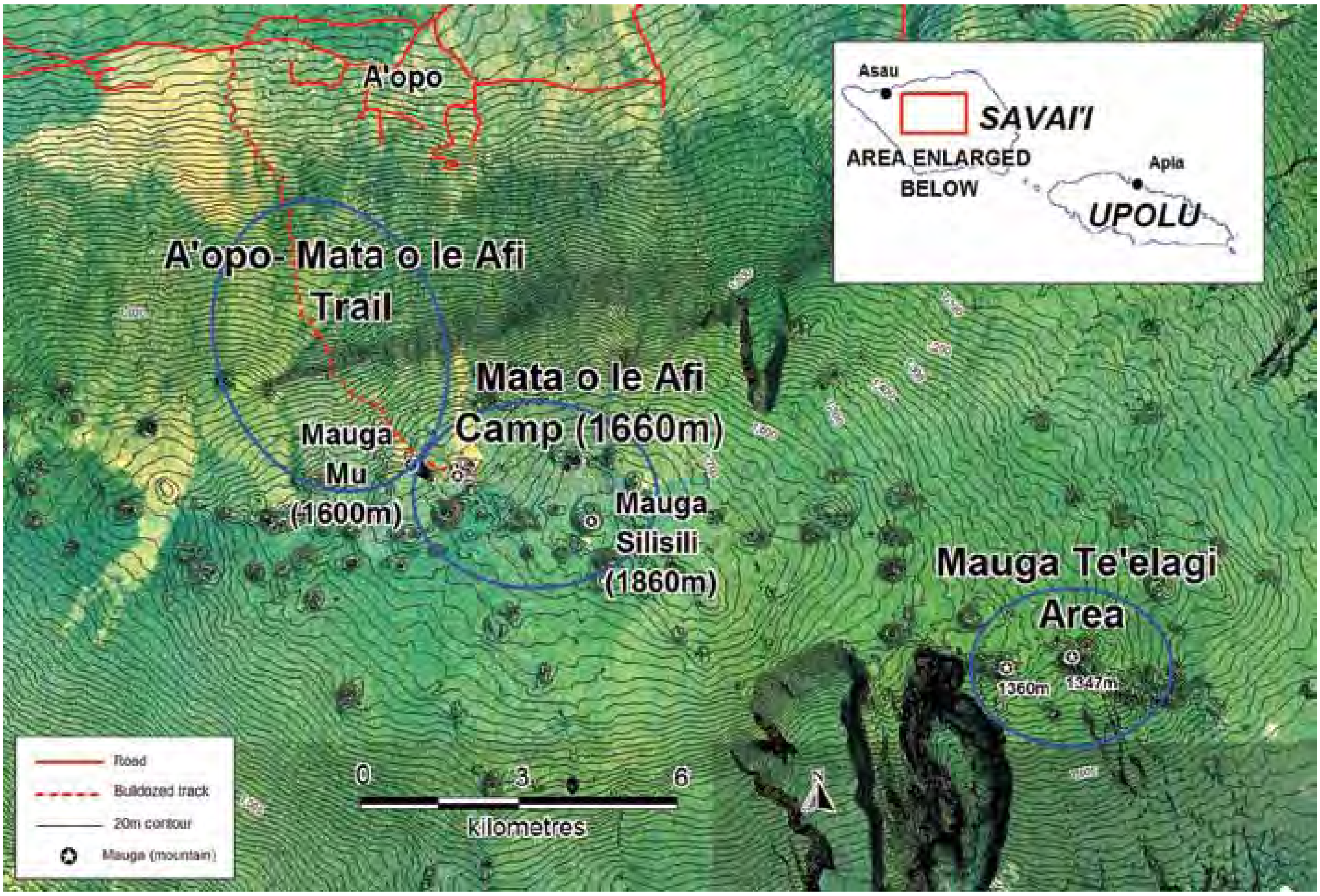
Helicopters provided by the NZ Defence Forces enabled access to many inaccessible craters in Upland Savai'i and mobilised the movement of heavy and bulky equipment. However, heavy rain and low cloud during the middle of the survey period hampered the ability to survey broadly across the interior of the island. Ultimately the survey focused on three main regions, the bulldozed road from A'opo to Mauga (Mount) Mū, the area around the main camp at Mata o le Afi to Mauga Silisili and finally two small craters to the south east of Mauga Te'elagi (Figure 1).

BIORAP SURVEY OVERVIEW AND OBJECTIVES

The BIORAP is an innovative biological inventory program developed by Conservation International and designed to use scientific information to catalyse conservation action. BIORAP methods are designed to rapidly assess the biodiversity of highly diverse areas and to train local scientists in biodiversity survey techniques.

Criteria generally considered during BIORAP surveys to identify priority areas for conservation across taxonomic groups include: species richness, species endemism, rare and/or threatened species, and habitat condition (Morrison and Nawadra 2009). Measurements of species richness can be used to compare the number of species between areas within a given region. Measurements of species endemism indicate the number of species endemic to some defined area and give an indication of both the uniqueness of the area and the species that will be threatened by alteration of that area's habitat (or conversely, the species that may be conserved through protected areas).

Figure 1. Key Survey Areas in the Savai'i BIORAP



Assessment of rare and/or threatened species that are known or suspected to occur within a given area provides an indication of the importance of the area for the conservation of global biodiversity (ibid). The confirmed presence or absence of such species also aids assessment of their conservation status. Many of the threatened species on IUCN's (International Union for the Conservation of Nature) Red List carry increased legal protection thus giving greater importance and weight to conservation decisions. Describing the number of specific habitat types or subhabitats within an area identifies the sparse or poorly known habitats within a region that contribute to habitat variety and therefore to species diversity.

The overall project objective was to: "Enhance knowledge of the status of the biodiversity of the upland forests of Savai'i and to establish immediate and long-term plans for its conservation".

The specific project objectives were to:

(i) Survey the fauna, flora and avifauna of the upland forests of Savai'i.

The project focused on surveys of the following taxonomic groups: birds, vascular plants, reptiles, land snails and moths. A particular focus of the bird surveys was to look for the Puna'e or Samoan Moorhen (*Gallinula pacifica*), the Manumea or Tooth-billed Pigeon (*Didunculus strigirostris*) and the Ma'oma'o (*Gymnomyza samoensis*). Observations and recording of introduced / invasive species and other threats to the conservation of the upland forests of Savai'i were also undertaken.

(ii) Train MNRE staff, local villagers and other interested groups and individuals in Samoa in surveying skills and techniques.

Training of MNRE staff, local villagers and other interested groups and individuals was an integral part of the project strategy, to ensure there was a transfer of knowledge to locals in order to enhance their knowledge and skills on the biodiversity of the upland forests of Savai'i and on key survey techniques.

(iii) Strengthen community involvement and participation.

An integral part of the project was to involve local Savai'i communities because, as the land owners, they have a key role to play in the conservation and sustainable use of the Savai'i rainforests. Consultations on the survey were conducted on the 18th and 19th April with representatives from 19 Savai'i villages, and approval was given for surveys to be conducted on village lands.

(iv) Develop conservation management policies and sustainability options.

Based on the findings and analysis of the field surveys, a set of recommendations which highlight key management and policy options that the Government and local communities should consider to protect the upland forests of Savai'i including key species and habitats found there, were produced.

SUMMARY OF BIORAP RESULTS BY TAXONOMIC GROUP

Key biological findings:

- The geological diversity caused by many episodes of volcanic activity has promoted a rich pattern of biodiversity in the landscape.
- Many plants, birds, insects and snails have an ancient association with the Samoan islands and have their stronghold in Savai'i's montane and cloud forests.
- Many moths and snails documented in this survey are examples that are unique and new to science.
- Invasive plants and insects typically impacting islands elsewhere in the Pacific are mostly not found in the upland forests and measures to limit their spread are possible.
- Wild cats, rats and pigs have penetrated some remote higher altitude areas with impacts on birdlife and native vegetation but natural values still persist and active management could conserve these values.

Flora and Vegetation

Two hundred and thirty-five vascular plant species were recorded in the upland area above 1,000 m elevation, including 71 endemics. A total of 196 voucher numbers were collected. The total number of species recorded from the area represents about one quarter of the known vascular flora of Samoa. Two species new to Samoa, both orchids, were recorded during the expedition, and they (*Calanthe* sp. and *Bulbophyllum* sp.) are now being studied; one or perhaps both of them representing new, unnamed species.

In the vegetation part of the study, six 500 m^2 plots were sampled between 1,600 and 1,250 m elevation. The diameter at breast height (dbh) of every tree over 5 cm dbh was measured, and tables of the results were prepared for each plot. Checklists of all vascular plants were made in these plots (as well as for the area as a whole) to determine the elevation range of the upland species. Based on the data and observations, four or five plant communities have been shown to exist in the area: montane forest, cloud forest, volcanic scrub, and *Carex* bog, and perhaps *Pandanus* swamp forest. Most of the area above 1,000 m elevation is montane forest, followed in total area by cloud forest. The main difference between the two seems to be the presence and dominance of *Reynoldsia pleiosperma* (vī vao) in the latter plant community. Volcanic scrub is found only on and around Mata o le Afi and Mauga Mū craters and their respective lava flows that extend a few km downslope. *Carex* bog was not visited by the botanical team, but is known to occur in waterlogged craters and depressions in the area. *Pandanus* swamp forest was seen by helicopter to occur around the margins of Lake Mataulano, but no areas of this vegetation, which may lie below 1,000 m in elevation, were visited.

From the data and observations, it appears that the vegetation is very healthy and that it has recovered from damage inflicted by two severe cyclones which hit two decades ago (Val and Ofa), and the forest is returning to its "natural" state. Only 17 alien species were recorded in the area, most of them occurring along the bulldozer track leading up to the site. Of these, only *Clidemia hirta* and *Mikania micrantha* (fue saina) invade native (secondary) forest as weeds, but were not found above 1,370 m elevation. The montane forest is in very good shape, with the worst threat being unauthorized roads being established in the area and related activities that allow the potential for weeds to enter the forest, thereby interrupting future natural succession.

Reptiles

The reptile team conducted a 21 kilometre transect from the coast east of Asau to the uplands, ending near Mauga Silisili at over 1720 m elevation. This transect covered the main habitats on Savai'i and allowed the team to determine where various reptile species and invasive species occurred across this elevational gradient. No previous reptile research had taken place on Savai'i above the elevation of A'opo Village. Limited sampling was also done around the Forestry Station in Asau.

The team detected 11 species of lizards during these surveys, which is the majority of species known from Samoa. Noticeably absent was the Pacific black skink (*Emoia nigra*), which is a dominant element of the Samoan lizard fauna. Also no individuals of the Pacific boa (*Candoia bibroni*) were detected despite the concentrated effort spent looking for them. One boa was detected by the avifauna team at their Site 1, by the TV tower on a log in a marsh. The invasive house gecko (*Hemidactylus frenatus*) was also not detected along the main transect, but was the most abundant gecko on buildings in Asau.

No reptiles were found above 1320 m elevation and most species were found significantly below there. Snake-eyed skinks (*Cryptoblepharus poecilopleurus*) were detected on Savai'i for the first time at Asau Getaway Resort then above the sawmill on the way to Mauga Mū. Since western Savai'i is so poorly known for reptiles, this is the first time many of these species were recorded from this part of the archipelago.

There were two important findings by the reptile team regarding ants in upland Savaii. Firstly it was found that the higher elevations on Savai'i (above 560 m) are apparently free of invasive ants. This is very important as Hawai'I, with a similar ecology, has invasive ants greatly impacting its high elevation ecosystems. The other important finding is that Yellow Crazy Ants are irrupting below 560 m on this side of Savai'i and where they occurred only a few species of lizards were able to persist with them.

Birds

The Avifauna team visited three main areas. The first was the forests above Asau towards Mauga Maugaloa; the second the forests above A'opo on the trail to Mauga Mata o Le Afi and beyond to Mauga Silisili; and the third included several craters nearer the centre of the island. The first two included areas were there had been possible sightings of the Puna'e or Samoan Moorhen last century and the third were sites, accessible only by helicopter, unlikely to have ever before been visited by scientists.

No trace of the Puna'e was found. Although there are still significant areas in which searches for this bird have not been undertaken, the survey tends to confirm the view that it is extinct (last confirmed report 1873). Only a single uncorroborated sighting of the endangered Manumea or Tooth-billed Pigeon was made, despite the presence of large numbers of its food trees, raising concern that its situation may now be critical. Reasonable numbers were recorded in a previous upland survey in 1996 but the area no longer seems to be a stronghold for this species. In addition, no Tuaimeo or Friendly Ground-doves were seen.

Small numbers of the endangered Ma'oma'o or Mao were found at the second and third sites, re-enforcing a picture that it has particular habitat requirements, which are now hard to find. Other forest birds were found in good numbers including the Matapaepae or Samoan White-eye which is found only in the Savai'i uplands. It was sufficiently numerous for the team to recommend a change in its current IUCN threat status.

One seabird, a Tahiti petrel, was found at an inland crater, a first record for this species in Samoa. This suggests that the uplands may still be an important area for nesting seabirds and further surveys are needed during the breeding season.

The survey found evidence that the uplands contain some of the same threats that have caused Samoa's rarest birds to largely disappear from the lowlands. Even the craters right in the interior had evidence of weeds and rats, while wild cats and feral pigs and cattle were encountered in other forest areas. Hunting was obviously occurring at the more accessible sites. Clear-felling over the past few years of the lowland forests of A'opo-Letui-Sasina, identified in 1992 as one of 5 key sites for biodiversity conservation in Samoa, will also have had devastating consequences for the rarer biodiversity in that part of Savai'i.

Moths and butterflies

The results of the surveys of moths and butterflies in the Savai'i highlands indicate a relatively unspoilt biodiversity and diversity of forest types once typical of high oceanic islands throughout the tropical Pacific. Of the 135 taxa in 21 families recognised in the upland survey, 44 species or 33% have been identified with published species names, but this includes the difficult and largely newly discovered micro-moth taxa. The majority (65%) of the large bodied macro-moths and butterflies are assigned to previously named species. Several new species were discovered among the smaller moth families including families; Crambidae, Tortricidae, Carposinidae and another eight families where new species await formal description.

Not surprisingly for a tropical upland, only two butterfly species were recorded in the Savai'i uplands and only one of those was above 1100 metres. The Big–eyed blue *Nacaduba dyopa dyopa* lives in forest with adults seen in glades and is native to islands of Fiji, Tonga and the Samoan islands. The other butterfly is the Samoan Ranger *Phalanta exulans*, which was common everywhere during the expedition. This vivid orange species feeds on the small tree *Melicytus samoensis,* which is scattered throughout forest and damaged forest areas. The Samoan Ranger is endemic to Upolu and Savai'i. Other butterflies can expect to be seen from time to time and this particularly includes Monarch *Danaus plexippus* and white butterflies in Family Peridae, which are known for wandering.

Progressing beyond 900 metres elevation, a distinct upland fauna includes moths that are widely associated with rainforest and shrubland on the Samoan Islands and elsewhere in west Polynesia and beyond. But Samoan endemics and specialists are also present reflecting the integrity, size and antiquity of the upland communities. In contrast with some of the modified and degraded Hawaiian montane and cloud forests, no insect pests were identified in the Savai'i uplands.

Land Snails

A total of 50 native landsnail species in 15 families, and one introduced species, were recorded from the 11 surveyed sites above 950 m elevation. The sole introduced species, *Bradybaena similaris*, was present up to c. 990 m elevation; the landsnail assemblages at sites at higher elevations contained native species only. The richness of native landsnail assemblages at the 11 sites ranged from 17-22 species per site, with a mean of 18.64 + 1.57 SD. Of the 50 native species, 14 species in eight families are named and have been recorded previously from lowland and/or foothill forest habitats on Savai'i; ten of these 14 species are endemic to Samoa. The other 36 native species, comprising 72% of the upland landsnail fauna, are unnamed, and have not been recorded previously from Savai'i or elsewhere. They include seven species of Charopidae, six species of Helicinidae, five species of Neocyclotidae, three species each of Punctidae and Vertiginidae, two species each of Assimineidae and Endodontidae, and one species each of Achatinellidae, Diplommatinidae, Hydrocenidae and Rhytididae. One of the unnamed species, *Sturanya* sp. 1, was also found at a site at c. 880 m elevation above Asau during the present survey, but the other 35 unnamed species were found above 950 m only. All of these unnamed species are probably Samoan endemics, and it is likely that many, if not all, are restricted to the uplands of Savai'i.

Most of the unnamed native landsnail species found above 950 m belong in genera that are also represented in the fauna at low to mid elevations on Savai'i, and all of these genera except the endemic Samoan *Ostodes* (Family Neocyclotidae), are widely distributed among other tropical South Pacific islands. However, the upland landsnail fauna on Savai'i also includes unnamed and presumably endemic species in the family Punctidae, which in shell morphology appear to be most closely related to subtropical and temperate taxa from the East Australian-New Zealand region. There are no previous records of native punctid snails from west Polynesia, and the only known records in southeastern Polynesia are an unnamed species from forest at 1700-1900 m elevation on Tahiti, and *Punctum polynesicum* from lowland habitats on Raivavae and Tubuai islands in the Austral group. Some of the unnamed species of Charopidae discovered during the May 2012 survey also belong in genera not previously recorded from Polynesia, but the systematics and biogeographic relationships of these taxa have not yet been determined.

OVERALL ASSESSMENT OF THE ECOLOGICAL VALUE OF THE SAVAI'I UPLAND FORESTS

The BIORAP survey reconfirmed the priority given to the conservation of the upland forests of Savai'i by the Government of Samoa. The Savai'i upland forests are nationally and internationally significant because of their large area, their relatively intact condition and limited invasion by pest and weed species, and because they contain many of the threatened terrestrial species in the country. With more than 450 km^2 of montane forest, 80km^2 of globally threatened cloud forest, and adjacent large blocks of lowland forest, along with the numerous volcanic craters and lava flows, the upland forests of Savai'i are unique by any measure and worthy of special conservation effort to ensure that natural values persist.

CONSERVATION RECOMMENDATIONS AND JUSTIFICATION

A number of conservation recommendations were made by the BIORAP team. These are summarised below along with justifications for the measures recommended.

1. Conserve the upland and adjacent lowland forests

The upland area above 800 m elevation should be given some form of official protection due to the rare ecosystems, significant biodiversity and fragility. The aim should be for the forests to be managed in a way that puts conservation as a priority, which largely means protecting them from the negative impacts we ourselves cause.

Conservation of the uplands needs to be advocated at two levels. Firstly, and arguably most importantly, it needs to take place with the local communities who communally own the uplands. Secondly, it needs to occur at Government level and to bring in the support of the international community. Over the past 20 years there have been many different approaches applied to the conservation of forested lands in Samoa. These include the creation of national parks and reserves, the establishment of rainforest preserves with international funding, working towards the development of community-based conservation areas such as those developed by the South Pacific Biodiversity Conservation Programme, and trying to establish businesses, such as ecotourism, that make non-destructive use of forests. Unfortunately positive outcomes have generally not been sustained and it would be worthwhile reviewing the various approaches that have been used and their efficacy.

In addition to conserving the upland forests, emphasis should also be placed on the conservation of adjacent lowland forests, especially for birds and flying foxes which make daily and seasonal movements between the two areas following the flowering and fruiting of different trees. For example, conserving the uplands alone is not going to save the Tooth-billed Pigeon. Although the upland area is remote and infrequently visited, the construction of the Mata o le Afi road shows how threats from invasive species, logging and habitat degradation can escalate very rapidly.

Given the ecological value and significance of the Upland Savai'i forest, there is potential for World Heritage, or Biosphere Reserve, status. Such status if obtained would make it easier to fundraise from the international donor community for the conservation of the forest as it would put the Upland Savai'i forests on the global conservation map.

In 2004 there were efforts by MNRE to develop an application to UNESCO for Biosphere Reserve Status for the Savai'i rainforest. However, the application was not completed due to misunderstandings by some local communities on the land tenure implications of the application. It is timely to reconsider the appropriateness and potential of an application for World Heritage or Biosphere Reserve status for Upland Savai'i.

There are two large projects currently being implemented by MNRE with Global Environment Facility (GEF) funds that promote the improved understanding and conservation of the upland forests of Savai'i: the Forestry and Protected Areas Management (FPAM) project, with FAO technical support; and the Integrating Climate Change Risk into the Forestry Sector (ICCRIFS) with UNDP technical support. Funds are therefore already available to implement some relevant activities that contribute to appropriate research and conservation of the Upland Savai'i forests.

It is recommended that:

- Different conservation approaches that have been applied both in Samoa and the wider Pacific are thoroughly reviewed, identifying their strengths and weaknesses, to come up with some novel approaches more likely to succeed.
- MNRE and partners ensure that the opportunity to use the two GEF funded projects- ICCRIFS and FPAM- to conduct appropriate research and to further the conservation of the Upland Savai'i rainforests and its ancient biodiversity character is retained.
- MNRE and partners provide discussions with relevant Savai'i communities agreeing the need to manage the upland forests in a sustainable manner.
- MNRE and partners implement conservation education and awareness programs with Savai'i communities, particularly with those having ownership over the lands with significant biodiversity.
- MNRE and partners investigate the potential of World Heritage or Biosphere Reserve status that would support Savai'i communities and MNRE in their endeavour to conserve the upland forests and report back to Savai'i communities.

2. Raise awareness on, and enforce, environmental laws

Samoa has numerous environmental laws that regulate a range of activities including land development, harvesting of endemic wildlife, logging, the extraction of water resources etc. However, many of these laws are not adequately enforced. For example, logging still occurs despite the absence of logging permits, and the hunting of endemic birds and bats, banned under the Protection of Wildlife Regulations 2004, is also not enforced. Enforcement of these laws is best done by relevant Government ministries in partnership with village matai (chiefly) councils.

The illegal bulldozed road from A'opo to Mata o le Afi is of particular concern. It is potentially devastating to the area as it opens up a pathway for the introduction of new weeds and other invasive species to the upland forest, as well as the potential for logging and hunting. The Planning and Urban Management Act 2004 is designed to regulate all developments, including road construction, but there is limited awareness amongst rural communities of its purpose, and there is very patchy enforcement of this law.

It is recommended that:

- MNRE and partners raise awareness among village communities on the purpose of environmental laws and the particular activities that are restricted or regulated.
- Environmental laws, such as those banning the harvest of endemic birds and flying foxes and regulating developments such as access roads, be enforced by the Government and village councils.
- The use of access roads that enter the relatively pristine environment of the uplands of Savai'i be regulated by village councils and local communities.
- A'opo village embrace the findings of this report and adopt its subsequent recommendation to ban access to the Mata o Le Afi road to all vehicles and road making machinery above 1000m elevation, with access to foot traffic only.

3. Manage the threat to the upland forests from invasive species

Invasive species, in particular weeds, pest insects (eg, ants), rats, mice, cats and pigs are a major threat to the ecological integrity of the upland forests. Biosecurity is not well understood by the local community and should be the focus for awareness and training opportunities in the future, especially for farmers, foresters and hunters.

It is recommended that:

- MNRE and MAF conduct practical biosecurity training with local Savai'i communities to obtain support and community understanding over the long term on the risks of introduction or spread of invasive species into the native forest.

- In a multi-year programme, weeds currently growing along the bulldozed road to Mata o le Afi be controlled- e.g., by removal or by shading them out by planting appropriate native plants common in the area. Bluebird Lumber should be asked to support this work.
- MNRE and MAF monitor the extent of invasive ant colonies along access routes to the uplands. This is because current surveys show that ants are not found above 560 metres.

4. Improve knowledge of the ecology and biodiversity of the upland forest

More information is needed to establish a fuller understanding of the ecology of the Savai'i upland forests and its biodiversity in order to aid site conservation and management. Due to bad weather only a fraction of the upland area above 1,000 m elevation was studied during the 11 day BIORAP survey; a number of geographic and taxonomic gaps are therefore priorities for future survey effort.

As noted, there is potential to develop synergistic research activities under existing projects such as the two GEF funded projects- the FPAM and the ICCRIFS.

It is recommended that:

- Follow-up surveys be conducted in areas not visited. This includes the eastern portion of Upland Savai'i, e.g., around Lake Mafane and Lake Mataulano and also around Mauga Maugaloa and Mulimauga in the north east of the island. This includes additional surveys of plants, land snails, birds and insects (especially at surface water streams), as well as surveys of invasive species such as cats, rats and mice.
- Surveys focus on craters with diverse habitats. Brief visits to several such sites located a Tahiti petrel and the potential for important seabird breeding areas. There were also indications of the presence of rails and crakes. The Puna'e could also have occupied wetlands such as those found in craters. If helicopters are available a future survey should aim to visit the other accessible ones and spend more time in those visited. The ideal time of year could be determined in relation to likely seabird breeding seasons.
- Surveys focus on specific species or taxonomic groups. There is an urgent need for more survey work on the tooth-billed pigeon which seems likely to require significant management to save it from extinction. In addition, Samoa's NBSAP (Government of Samoa 2001) includes an action 'Carry out a survey to determine the status of Samoa's seabird population'. This could now be considered more important following the lack of seabirds found during this survey and the fact that two species identified have not apparently been recorded in Samoa before.
- Survey the traditional knowledge of village people on their relationship and experiences with their environment and natural resources as this will provide a baseline of data on how the diversity of Upland Savai'i looked during the last millennium, and provide village councils and MNRE with key clues to develop appropriate future management approaches.

5. Manage ecotourism to the upland forests sustainably

The upland forests of Savai'i have considerable potential as an ecotourism destination. Samoa's highest mountain (Mauga Silisili) is located in these forests, as well as interesting volcanic landscapes, threatened biodiversity and a range of unusual vegetation types, such as montane bogs. A number of tourists already climb Mauga Silisili every year but with trail and infrastructure improvement and better marketing there is potential for more visitors and thereby more income to local communities. However, ecotourism must be planned properly and managed sensitively in close collaboration with local communities so as not to damage the very values that tourists come to see.

It is recommended that:

- A partnership between the Samoa Tourism Authority (STA), MNRE and village communities is developed to prepare and implement a sustainable development plan for ecotourism development of Upland Savai'i.
- Ecotourism activities be managed carefully so as to not damage the vulnerable and unique upland forests and lava flows. For example, consistent and reasonable fees for visitors need to be identified, forest trails need to be better marked and benched, appropriate policies put in place to minimise biosecurity

- risks such as visitors spreading weeds by accident, guides should be better trained, the potential visitor campsite at Mata o Le Afi would be properly established under a plan with a tentsite, compost toilet and water tanks and no damage to the lichen on the ash plain allowed.

6. Implement management regimes for highly threatened species

Seven species recognised as globally threatened on the IUCN Red List of threatened species are found in the Upland Savai'i forests including four bird species, two plants and one mammal, the Samoan flying fox. There are many other species that are known to be threatened but are not yet on the IUCN Red List due to a lack of data to prove their threat status.

Management regimes need to be established for the threatened species. This may involve a range of complementary actions, such as raising awareness amongst local communities on these threatened species and what is threatening them, enforcing harvest bans, controlling the abundance of cat and rat predators and conserving forest habitat. Of particular concern are two bird species- the Manumea (*Didunculus strigirostris*) and the Ma'oma'o (*Gymnomyza samoensis*).

In particular it is recommended that:

- Efforts to conserve the Manumea are increased. The results of the BIORAP, coupled with observations from Upolu where the species has proved hard to locate at previous sites, suggest this species to be in a critical situation. The immediate priority is further survey work on Upolu where it is hoped that birds can still be found in some of the relatively accessible sites identified in the Manumea species recovery plan. Such sites potentially lend themselves to the kind of management interventions that may be needed to bring about any recovery.
- While Mao were recorded at several sites this does not significantly change the picture for this species. Their presence does not mean that the population is doing well. Research on Upolu is showing that many pairs are still not successfully producing enough chicks due to the high predation rate on nests by introduced rats. The potential benefits of seasonal local suppression of rats and cats for birdlife should be weighed up, but the survey has clarified that, for the Mao at least, protecting upland areas is likely to help maintain this species in Samoa.

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CHAPTER 1
Report on the plants of Upland Savai'i

ART WHISTLER

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1. SUMMARY

The botany of Upland Savai'i was studied from 20 to 31 May 2012. The original plan, as envisioned, called for a transect to be cut from east to west across the length of montane Savai'i, but because of the availability of New Zealand Defence Force helicopters, the plan was changed to include airborne transport to selected upland sites. Unfortunately, the best-laid plans were hampered by bad weather, logistic problems, and illness. Unexpected rainy weather hit Samoa during the middle of the expedition, preventing the helicopters from being used effectively. This resulted in only the upland area from Mauga Mū eastward to Mauga Silisili, and down to the "car park" at 1,000 m elevation, being studied. Logistically, communication equipment proved troublesome, and some of the collected specimens mysteriously disappeared during their intended helicopter transport to where they were to be dried. Health wise, another botanist enlisted to help the consultant with the field worked had to drop out because of medical problems just before the expedition was to start, and unrelated to that, most of the botanical team got sick at the base camp in the middle of the expedition.

However, much valuable information was collected. Floristically, 235 vascular plant species were recorded in the upland area above 1,000 m elevation, including 71 endemics. A total of 196 voucher numbers was collected. Whenever possible, four sets of duplicates were prepared for each of them. One of the sets is to stay in Samoa, and the other three will be sent to the University of Hawai'i Botany Department herbarium, the University of the South Pacific herbarium, and the Auckland Museum herbarium. The total number of species recorded from the area represents about one quarter of the known vascular flora of Samoa. Two species new to Samoa, both orchids, were recorded during the expedition, and they (*Calanthe* sp. and *Bulbophyllum* sp.) are now being studied; one or perhaps both of them represent new, unnamed species.

In the vegetation part of the study, six 500 m^2 plots were sampled between 1,600 and 1,250 m elevation. The dbh of every tree over 5 cm dbh was measured, and tables of the results were prepared for each plot. Checklists of all vascular plants were made in these plots (as well as for the area as a whole) to determine the elevation range of the upland species. Based upon the data and observations, four or five plant communities have been shown to exist in the area: montane forest, cloud forest, volcanic scrub, and *Carex* bog, and perhaps *Pandanus* swamp forest. Most of the area above 1,000 m elevation is montane forest, followed in total area by cloud forest. The main difference between the two seems to be the presence and dominance of *Reynoldsia pleiosperma* (vī vao) in the latter plant community. Volcanic scrub is found only on and around Mata o le Afi and Mauga Mū craters and their respective lava flows that extend a few km downslope. *Carex* bog was not visited by the botanical team, but is known to occur in waterlogged craters and depressions in the area. *Pandanus* swamp forest was seen by helicopter to occur around the margins of Lake Mataulano, but no areas of this vegetation were visited, and, in any case, it may lie below 1,000 m in elevation.

From the data and observations, it appears that the vegetation is very healthy and that it has recovered from damage inflicted by two severe cyclones that hit two decades ago (Val and Ofa), and the forest is returning to its "natural" state. Only 17 alien species were recorded in the area, most of them occurring along the bulldozer track leading up to the site. Of these, only *Clidemia hirta* and *Mikania micrantha* (fue saina) invade native (secondary) forest as weeds, but were not found above 1,300 m elevation. The montane forest is in very good shape, with the worst threat being unauthorized roads being established in the area.

2. INTRODUCTION

The following botanical study is part of the BIORAP (Biological Rapid Survey) carried out in the upland (further referred to here as "montane") region of Savai'i, Samoa, by a multidisciplinary and multinational team of experts from 20 to 31 May, 2012. The upper slopes of the 1,860m-high island are covered with a dense, relatively undisturbed rainforest, which accounts for the island's 23rd place in a ranking of the conservation value of South Pacific islands (SPREP 2012). When combined with the montane forest below it, the area probably comprises (with the possible exception of the Big Island of Hawai'i) the largest intact block of tropical rainforest in Polynesia.

As originally planned, the study was to encompass the montane region of the central part of the island from one end to the other, but due to logistics problems and weather, the area studied was in reality restricted to the montane area above A'opo, around the volcanoes of Mauga (Mount) Silisili (1,860 m), Mata o le Afi (ca. 1,660 m), and Mauga Mū (ca. 1,600 m). The lower boundary began at about 1,000 m elevation at a "car park" at the upper end of the 4-wheel drive track running from the coast near A'opo up to the where the bulldozer track becomes impassable to vehicles.

The botanical study comprises two aspects, flora and vegetation. The flora of an area is usually thought of as a list that includes all the plants occurring in that area. This list can include all flowering plants, all vascular plants (flowering plants, gymnosperms, and ferns), or all plants (including algae, lichens, etc.). The present study comprises the vascular plants. No comprehensive flora has been done for Samoa, but much relevant information is found in a number of publications over the last 150 years, especially those of A.C. Smith (1979–1996), and the Consultant, who has been working on the flora of the archipelago for 40 years (see Whistler 2004 and others).

Plants can be classified by their distribution: they are either native, i.e., they occur naturally in the area (having arrived by non-human transport) or they are alien (introduced species that arrived by direct or indirect human transport). Alien species can be further divided into those introduced by Polynesians (i.e., species brought in prior to ca. 1830, and called "Polynesian introductions") and those introduced in modern times (i.e., after about 1830, and called "modern introductions") by Europeans or by Polynesians travelling by means of western transport (boats, and nowadays, airplanes). Native plants can also be further divided into two categories, endemic and indigenous. Endemic refers to plants restricted to a certain area; plants endemic to Samoa are found only in Samoa. Indigenous refers to native species with a wider distribution, i.e., they are also found outside of Samoa. The vast majority of the species found in montane Savai'i are native—mostly indigenous species. Only one possible Polynesian introduction (*Solanum americanum*) was found among the species encountered during the present survey. Several others are modern introductions, all of them weeds. In terms of biodiversity, the most important species are endemic native species, because if endemic species disappear from Samoa, they disappear from the world.

The vegetation of an area is the way the species are arranged. The spatial distribution of plants is usually thought of in terms of "plant communities," which are defined as units of similar vegetation distinguished from other units by their structure, species composition, and habitat. The mangrove community, for example, is a forest occurring in coastal saline areas and dominated by mangrove species. Many of the plant communities are further divided into "associations" based upon their flora—usually upon their dominant plant or plants. The mangrove community, for example, is often divided into a *Bruguiera* association and a *Rhizophora* association, named after the tree species that dominate them.

As will be explained in the vegetation section below, the highest elevation regions of montane Savai'i are dominated by species that collectively comprise the plant community called "cloud forest." Lower in elevation and somewhat different in species composition is a community known as "montane forest." Also present in montane Savai'i are two or three other plant communities: "upland volcanic scrub," "*Carex* bog," and possibly *Pandanus* swamp forest (see below). Some of these communities grade into each other, like the montane and cloud forests, but others, such as upland volcanic scrub, have distinct boundaries that correspond to the edge of lava flows or cinder cones. The study of plant communities can be qualitative, such as those that determine which species are present in a type of vegetation (e.g., a lava flow), or it may be quantitative, which involves the determination of how much there is of each species, i.e., how many individuals are in a plot of fixed size, or total trunk cross-sectional area of each species in a plot, as is explained in the methodology section below. A quantitative survey is by far the better method, but time constraints do not always make using it feasible. The plant communities present in montane Savai'i are described in the vegetation section below.

2.1. The Montane Flora of Samoa

The first plant collections from Savai'i were apparently made during the visit of the United States Exploring Expedition (USEE) to the island in 1839 (Pickering 1876). The expedition's botanists visited the summit area of Savai'i, judging by the inclusion of cloud forest species among their collections. More botanical collections were made in Samoa during the next half century by amateur collectors, most notably Dr. E. Graeffe, a Swiss physician (intermittently in Samoa from ca. 1862 to 1872); Rev. T. Powell, an English missionary (in Samoa ca. 1848 to 1885); and Rev. J. Whitmee, another English missionary (in Samoa ca. 1875–1885). Their collections were virtually unpublished, and, unfortunately, only limited information is recorded on the specimens, sometimes lacking even an indication of their island of collection. However, all three of these collectors apparently visited the summit of Savai'i, based upon the composition of their collections.

Comprehensive studies of the flora began during the last decade of the 19th century, when the German botanist F. Reinecke worked in the archipelago from 1893 to 1895 and published his *Die Flora der Samoa-Inseln* (Reinecke 1896, 1898). He was followed by F. Vaupel, a German physician and amateur botanist whose collections date from 1904 to 1906 (and were partially treated in Lauterbach 1908), and K. Rechinger, who visited Samoa in 1905 and published a series of reports (Rechinger 1907–1915) based on his collections. All of these collectors are known to have visited the montane region of Savai'i. They were followed by E. Christophersen, who collected in Samoa in 1929 and 1931 and published his two-volume work Flowering Plants of Samoa (Christophersen 1935, 1938). Christophersen also visited the montane region of Savai'i during both of his visits to Samoa. The ferns gathered by all the collectors mentioned above were documented in a fern floristic study (Christensen 1943), who did not actually personally visit Samoa.

Since Christophersen's visits to Samoa, only a few other botanists are known of have made collections in montane Savai'i. Both M. Bristol (in 1968) and P. Cox (in the 1980s) collected there, but accounts of their collections have not been published. Prior to the current expedition, the Consultant (Whistler) visited the cloud forest of Savai'i in 1975, 1992, and 1996, but the three visits were all centred around Mata o le Afi and Mauga Silisili. The results of the first visit were published by Whistler (1978), and the third visit was published by Schuster *et al*. (1999). The only checklists of plants recorded in the montane region are found in these latter two publications.

2.2. The Montane Vegetation of Savai'i

The Whistler publication (1978) was a result of an expedition to the Mata o le Afi area of the island in 1975. Based upon a 120-tree survey, observations, checklists, and collections, he recognized four plant communities in the area: "cloud forest"; "montane meadow"; "montane lavaflow scrub: and "ash and cinder cone scrub". Since the study was only around Mata o le Afi, no area of montane forest was included. The montane meadow is now called Carex Bog, a division of the marsh community. The two types of volcanic vegetation he recognized are now considered to be a part of volcanic scrub, more specifically, the division of the volcanic scrub community known as "upland volcanic scrub." The next vegetation study dealing with the montane area of Savai'i was not actually a vegetation survey, but a forestry inventory (Chandler *et al*. 1978) that dealt primarily with timber species. Although it was not an academic study, the discussions and data presented are very useful in understanding the forest composition of Upland Savai'i. That study was followed by a mapping of the vegetation of all of Samoa (Pearsall & Whistler 1991), including montane Savai'i. It provided large-scale maps of the different communities they delineated, but included only brief field observations rather than extensive collection of quantitative data. A more comprehensive study of the uplands was done by Schuster *et al*. (1999), based on a visit to the Mata o le Afi area in 1996. It included several plots in montane and cloud forest (see Appendix 1.3), and a description of the plant communities found in montane Savai'i. Based upon all these studies, Whistler (2002) published a book on the vegetation of Samoa, which established the plant communities currently recognized in Samoa. Apparently no field studies have been done in montane Savai'i since 1996.

3. METHODOLOGY

The original plan for the botanical study of montane Savaiʻi envisioned a series of a dozen or more 1,000 m^2 plots to be situated along a transect extending east to west across the island at a variety of upland elevations. However, due to difficulties in logistics and access through the dense rainforest, and the availability of New Zealand Defence Force helicopter support, the plan was modified to have helicopters drop off the survey crew at different places in the area in order to do their studies. However, due to unusually wet weather and limited places the helicopters could land, the airborne support was severely hampered. The botany team was not able to visit any of the areas away from the base camp (at Mata o le Afi) that were slated for exploration because the wet weather made the selected landing sites in marshes change into lakes. Also hampering the implementation of the research plan was the loss of the second botanist, who had to withdraw at the last moment for health reasons, leaving only the Consultant to organize the work. Consequently, the scope and the range of the surveys were greatly curtailed.

As noted above, the survey included two aspects: flora and vegetation. Prior to the study, the consultant did a review of the botanical literature to get an idea of which species to expect in montane Savaiʻi above 1,000 m in elevation. A checklist was begun during the walk up from the car park above Aʻopo at the end of the drivable 4-wheel drive road at ca. 1,000 m elevation up to the base camp at ca. 1,600 m. Further species were added during reconnaissance of the area around Mata o le Afi, Mauga Mū, and the area eastward toward Mauga Silisili. Checklists were also made in each of the six plots sampled, and a checklist was made in the forest above the car park at 1,000 to 1,050 m elevation. All new species encountered during these searches were added to the comprehensive checklist, which is shown in Appendix 1.1.

In addition to compiling the comprehensive checklist, voucher specimens were collected for most species recorded. Voucher specimens "vouch" for the presence of species in an area, because species on the checklist are sometimes called into question. Whenever possible, four sets of each specimen were made. These will be distributed to the MNRE, the University of Hawaiʻi Botany Department herbarium, the University of the South Pacific Regional Herbarium, and the Auckland Museum herbarium. The specimens collected during the fieldwork were numbered, put into newspapers, and bundled up for transport back to Āsau. An herbarium plant drier obtained from the National University of Samoa was transported to the Va-i-Moana Hotel in Āsau and was set up by a volunteer entrusted with the task. The plan was to send the fresh specimens down by helicopter to the drier every other day or so. Unfortunately, the first bundle of specimens collected during the expedition were loaded onto the helicopter at the base camp, but for reasons that will probably remain forever unknown, the bundle disappeared in transit. This lost shipment comprised all the specimens collected during the initial walk up to the base camp at Mata o le Afi—about 12% of all the specimens collected. The rest of the specimens were later hand carried down to Āsau without further loss.

The bundles were opened at the drier and the individual specimens in newspaper were put between cardboard "corrugates" and then placed into a plant press. The press was then put into the drier, which was powered by several incandescent light bulbs to produce the desired heat. As originally set up, this apparatus did not prove as effective as hoped, so modifications were made in order to speed up drying, e.g., enclosing the bottom with cardboard, adding more light bulbs, etc. When the specimens were dry, they were taken out of the press, collated, and wrapped up for shipment back to Āpia, where they were placed into the four aforementioned sets ready for shipping at the appropriate time. At the time of this writing, most of the specimens are still in Āpia awaiting shipment.

The Consultant recognized most of the species collected, but some needed further research via the literature and the Consultant's notes to determine their identity. Those still not recognized were later studied by the Consultant after he returned to Honolulu. Two species found during the study appear to be new records for Samoa, and one of them, at least, is an apparently a new species. These two species, both orchids, were sent to Kew Garden to the orchid expert (Phil Cribb) for further identification and possible naming. The voucher specimen numbers are shown in flora checklist in Appendix 1.1.

The vegetation was sampled in six study plots 500 m^2 in area (Fig. 1.1). Three of these plots were above 1,500 m around the base camp in vegetation that is now determined to be cloud forest. The other three were established along the bulldozer track leading down to the car park at ca. 1,000 m elevation, in montane forest at 1,460 m, 1,350 m, and 1,250 m. An additional checklist of all species found in the area between 1,000 and 1,050 m elevation was made just above the car park. The tree plot data is shown in Appendix 1.2, and elevation data of all species is shown in the checklist in Appendix 1.4. The original plan was to make the plots permanent with GPS data and boundary markers, but the markers (PVC pipes) did not make it up to the study site.

Figure 1.1. Location of Botanical Survey Plots

When establishing the plots, an area of representative vegetation (i.e., one without disturbance and in homogeneous forest) was selected and a 50-m tape was laid out through the forest. The plot comprised the area extending out 5 m from each side of the line, making the plot 50 x 10 m in extent. The survey crew then went down the line measuring all trees within 5 m of one side of the line. No boundaries were established ahead of time; any tree near the imaginary boundary had its distance from the line measured, and those just inside the boundary were often marked with plastic flagging tape to help visualize the boundary. Once the 50 x 5 m side was finished, the survey team reversed directions and measured all trees in the other half of the plot. The trees were measured using a dbh tape placed around the trunk at breast height (dbh). If the trunk comprised multiple stems, the measurement was made lower down the trunk, or depending upon the shape of the tree, on all sufficiently large branches at breast height. The results of the measurements were 79 to 162 trees with a dbh of over 5 cm per plot.

After the plot was sampled, the data was collated and "relative dominance" for each species was calculated by dividing the total stem cross-sectional area of the species by the total stem cross-sectional area of all species. The stem area of an individual tree is determined by measuring the dbh, squaring this diameter, and multiplying the figure by 0.789 (the ratio of the area of a circle, i.e., a tree trunk cross-section, to the area of a square). In mathematical terms, this is πr2. The total basal areas of all of the trees were summed up, and the species were then placed in a table in descending order of relative dominance (see Appendix 1.2). The first column to the right of the species name shows the number of individuals of that species in the plot. The second column shows the number of sampled individuals having a basal diameter of 15 cm or more, which is a simple indication of the relative size of the individuals (i.e., how many of the individuals were large trees). The third column shows the total basal area of each species. The fourth and last column shows the relative dominance of each species. The total number of trees, the total number over 15 cm dbh, and the total tree basal area of the plot are shown below each table.

Only trees were sampled quantitatively in the plots. Since dbh does not work with non-tree vegetation, just quantitative notes were taken on the ground cover species, epiphytes, and vines in the forest. On the areas of volcanic scrub, simple notes were taken indicating all species present and which ones were dominant. One frequency sample of epiphytes on small trees in volcanic scrub was made, but this is not really quantitative. Based upon the dbh measurements, checklists of species found, and notes on abundance of non-tree species, the vegetation description in the following section was written.

4. THE VEGETATION

Several plant communities occur in montane Savai'i, as described in Whistler (2002): *Carex* bog, *Pandanus* swamp forest, volcanic scrub, montane forest, and cloud forest. Wetlands are divided into two main types—swamps, which are dominated by woody vegetation, and marshes, which are dominated by herbaceous vegetation. Marshes in Samoa can be divided into several subtypes, including lowland marshes, upland marshes, montane meadows (which may dry out part of the year), and *Carex* bogs. Only the latter type is found in montane Savai'i. No areas of montane swamp forest have been sampled on Savai'i, but at least one type, dominated by a species of screwpine, is probably present. The vast majority of montane Savai'i is covered with montane forest and cloud forest. There are major differences in species composition between the two, which are probably related to the amount of rainfall and humidity, and perhaps to temperature, but the two communities blend into each other, making it impossible to draw boundaries between them. The four communities recognized here to occur in montane Savai'i, as well as one that may be there, are described below.

4.1. Carex Bog

This is the herbaceous vegetation that dominates high elevation areas having waterlogged soil. This community is not known from Upolu, which apparently lacks the requisite elevation. The herbaceous vegetation types in high elevation craters on Upolu are classified as montane marshes and montane meadows, which, when undisturbed, are dominated by several herbaceous species. The dominant species of the *Carex* bogs of Savai'i, two species of *Carex*, are virtually absent from Upolu. *Carex graeffeana* has never been recorded from Upolu, and *Carex maculata* was recorded only once. Herbaceous hydrophytes (aquatic plants) dominate these areas of waterlogged soil because native trees do not appear to be able to colonize them. In addition to the differences in species composition, bogs differ from marshes typically by the presence of a layer of peat, but no soil samples are known to have been taken in the *Carex* bogs and scant information about them is available.

Carex bogs are known from several localities in montane Savai'i, mostly inside old volcanic craters. One large area of bog, in two patches, is found in a shallow depression located just south of Mauga Silisili (Fig. 1.2). Virtually no studies of the montane wetland vegetation of Savai'i have been done, in contrast to Upolu, where a number of them have been visited and described (Whistler 2002). Because of circumstances beyond the control of the survey team, areas of this type of vegetation were not visited during the present expedition. However, the *Carex* bog was described in some detail by Whistler (1978, 2002). In the 1978 study of the Mata o le Afi, Whistler described the "montane meadow" (=*Carex* bog) as follows:

"These meadows occur in the cloud forest in old volcanic craters and poorly drained valleys. Two such meadows were visited during the survey, but neither one was sampled quantitatively. The first is the shallow crater of a volcanic cone south of Mauga Silisili at an elevation of 1650 m. The vegetation of the crater floor consists of low herbaceous plants mostly less than 30 cm high. The dominant species are *Carex samoensis* [=*C. maculata*], *Paspalum orbiculare*, and *Lycopodium cernuum*. It is likely that during heavy rains a shallow lake is formed within the crater. The other, larger meadow is a flat area south of and adjacent to the base of Mauga Silisili is dominated almost entirely by a dense cover of the sedge *Carex graeffeana* growing up to 1 m high. In the centre of the meadow is a narrow trough [where] there was some standing water."

Figure 1.2. Two patches of *Carex* bog located just south of Mauga Silisili (Photo by J. Atherton).

4.2. Pandanus Swamp Forest

Not all of the wetland vegetation in montane Savai'i is dominated by herbaceous species. Hydrophytic trees sometimes dominate, perhaps mostly on the edges of marshes where the soil is not so waterlogged or not waterlogged for extensive periods. Swamp forest dominated by several tree species are reported from Upolu, and to a lesser extent, Savai'i, but most of these are found only in the lowlands and foothills. The only swamp forests reported from high elevations in Samoa are dominated by species of the screwpine genus *Pandanus*. *Pandanus turritus* (fasa), an endemic species of screwpine (also known as by its synonym, *Pandanus lanutoensis*) is difficult to distinguish from *Pandanus tectorius* except for where it grows. This screwpine is reported between 300 and 900 m elevation on Upolu, usually (but not always) in montane craters. The vegetation in some of Upolu's montane craters is dominated by *Pandanus turritus,* but in others, meadows and marshes dominated by sedges and grasses prevail. Still others contain lakes surrounded by either *Pandanus turritus* or sedges on the edges. It is uncertain what features determine whether the crater vegetation becomes a swamp forest or a montane marsh (as discussed earlier), but there appears to be some kind of succession taking place. Where *Eleocharis* and screwpines occur together in the Upolu craters, the sedge is usually closer to the pond edge than the screwpines, suggesting that the latter may be unable to survive where the soil is too waterlogged for them. However, this point needs further study. Similar craters on Savai'i may contain the same or similar freshwater swamps, but these have not been studied. Lake Mataulano, which lies at about 900 m elevation, has a margin of screwpine around its edges (Fig. 1.3). There is no evidence that this kind of vegetation is found above the 1,000 m elevation lower boundary of the study area.

Figure 1.3. Lake Mataulano with a fringe of *Pandanus* sp. (screwpine) along its margin (Photo by S. Chape).

4.3 Volcanic Scrub

Two areas of upland volcanic scrub are known from montane Savaiʻi, both of them created by eruptions occurring in 1902. Mauga Mū, whose summit reaches about 1,600 m elevation, comprises a single large crater and a resulting lava flow that extends downslope about 3 km. Mata o le Afi comprises a series of smaller craters at about the same elevation as Mauga Mū, and is surrounded by extensive areas of ash virtually devoid of vegetation other than lichens. A lava flow similar to that occurring below Mauga Mū extends downslope about 4 km. These volcanic areas are quite different from lowland volcanic scrub in that they range in elevation from 1,150–1,500 m, while the lowland volcanic area from Matavanu is below 650 m elevation. Both upland and lowland lava flows are similar to each other in structure, but there is very little overlap of species between the two. Three factors determine what vegetation occurs on them: substrate, age of the flow, and elevation. Two main kinds of lava substrate are recognized, ʻaʻa and pahoehoe. ʻAʻa lava is a rough or rubbly, while pahoehoe is a smooth, billowy, or ropy. Although the two sometimes intergrade, they are usually fairly distinct and recognizable.

Based on the current study, the vegetation of the Mauga Mū lava flow is dominated by shrubby and herbaceous species (Fig. 1.4), the most prevalent of which is the Samoan blueberry *Vaccinium whitmeei*, and to a much lesser extent, *Wikstroemia foetida* (fau mū). Stunted cloud and montane forest trees are also common, but are relatively scattered and do not comprise a forest. The most common tree species are *Spiraeanthemum samoense*, *Glochidion christophersenii* (masame), *Coprosma Savaiiense*, *Geniostoma rupestre* (tāipoipo), *Reynoldsia pleiosperma* (vī vao), and *Metrosideros collina*. Although no quantitative studies were done there, a number of herbaceous species were recorded to be common, especially the ferns *Nephrolepis pseudolauterbachii*, *Humata serrata*, *Blechnum orientale*, *Blechnum vulcanicum*, *Dicranopteris linearis* (asaua); the fern allies *Lycopodium cernuum* and *Lycopodium venustulum*; the orchids *Glomera reineckei* and *Dendrobium* *reineckei*; the grass *Imperata cylindrica*; and the vine *Hoya filiformis*. The vegetation of the Mata o le Afi lava flow is very similar to that of the Mauga Mū flow, with *Vaccinium whitmeei* being the dominant species. The same trees and shrubs that are common on the Mauga Mū flow, e.g., *Coprosma Savai'iense*, *Spriaeanthemum samoense*, and *Wikstroemia foetida*, were recorded as common but scattered on the rough lava flow. The most abundant herbaceous species here is probably the grass *Imperata cylindrica*, with lesser amounts of the ferns and fern allies *Lycopodium cernuum*, *Lycopodium venustulum*, *Nephrolepis pseudolauterbachii*, and in some places, *Dicranopteris linearis*.

Figure 1.4. Volcanic scrub vegetation on the Mauga Mū lava flow dominated by Samoan blueberry (Photo by A. Whistler).

The vegetation on the two cinder cones is similar to that found on the lava flows, since they are both made of volcanic material (ash and lava). The scrambling shrub *Vaccinium whitmeei* is the dominant species on the slopes of the two cones. Scattered trees mostly less than 3 m in height are found throughout the area (Fig. 1.5), the most common of which are *Spiraeanthemum samoense*, *Weinmannia affinis*, *Geniostoma rupestre*, *Glochidion christophersenii*, *Wikstroemia foetida* (more of a shrub), and *Coprosma Savai'iense*. The most attractive plant here is the endemic shrub *Cyrtandra nitens*, whose large white flowers are very showy. There are no doubt subtle differences in the relative amounts of the common species caused by the differences in substrates, but time was lacking to do more extensive studies to determine what these differences are.

Figure 1.5. Scattered trees in the volcanic scrub vegetation on the slopes of Mauga Mū (Photo by A. Whistler).

One difference between the vegetation on the two cones is the presence of extensive areas of flat and gently sloping cinder around Mata o le Afi. In some places, this cinder is covered with a layer of white lichen, with vascular plants virtually absent (Fig.1.6). In other places, such as the ash plain just to the east of Mata o le Afi, the ground cover is dominated by herbaceous species, mostly the native grass *Imperata cylindrica*. Less frequent but still common is the creeping fern ally *Lycopodium venustulum*. One unique species found here is the tiny orchid *Spiranthes sinensis*. Unlike in previous visits to the area by the Consultant, this species was rare this time, with only two individuals reported. Also present were very low-growing white and red lichens.

Figure 1.6. Areas of cinder at Mata o le Afi dominated by white lichens (Photo by A. Whistler).

The low stature trees of the areas of cinder cone vegetation are home to a number of epiphytes, including the ferns *Humata serrata*, *Belvisia vaupelii*, and *Selliguea feeoides*, and the orchids *Coelogyne lycastoides*, *Dendrobium reineckei*, and *Dendrobium mohlianum*. During the study, epiphytes were studied on ten relatively large *Weinmannia affinis* trees (the dominant tree species on this volcanic substrate, and the one most favoured by epiphytes). By far the most common and abundant epiphyte was the clump-forming orchid *Dendrobium reineckei*, which was found on 7/10 of the trees. Also common were the epiphytic orchid *Dendrobium vagans* and the epiphytic fern *Humata serrata*. Less common species included the orchids *Eria robusta*, *Bulbophyllum* sp., *Bulbophyllum betchei*, and *Dendrobium mohlianum*. *Vaccinium whitmeei* also appeared to be a common epiphyte, but it is not clear if this was actually an epiphyte or was growing up from the ground and through the mossy layer covering many of the scrubby trees.

4.4 Montane Forest

Montane forest is the rainforest covering the mountain slopes and plateaus of the island, and is characterized by the dominance of *Dysoxylum huntii* (maota mea). In four montane forest plots ranging from 930–1,320 m elevation on Savai'i and Upolu, *Dysoxylum* averaged 37% in relative dominance (Whistler 2002). Botanically, the upper boundary of the montane forest corresponds to the elevation where *Reynoldsia pleiosperma* (vī vao) replaces *Dysoxylum huntii* in dominance, and the lower boundary to where lowland forest, typically dominated by *Syzygium inophylloides* (asi) and several other species, are replaced by *Dysoxylum huntii*. It is difficult to accurately determine the elevational range of this forest, since so few botanical and forestry surveys have been done in this zone. On Savai'i, montane forest apparently starts between 600 and 1,000 m, depending upon the side of the island (the north-facing "leeward" side or the south-facing "windward" side), and extends up to perhaps 1,500 m, where it is replaced by cloud forest. Its elevational boundaries are by no means distinct, because of the way the dominant species appear and disappear with varying elevation, and this can lead to problems in classification of some forest areas. Montane forest blends into cloud forest, with the main difference being perhaps the dominance of *Reynoldsia pleiosperma* (vī vao) in the latter. Montane forest probably has the most diverse flora of any community of Samoa. It is home to more species of trees, lianas, ferns, and orchids than any other vegetation type in Samoa.

Table 1.1. Relative dominance (%) of cloud and montane forest trees in six plots.

Elevation (m)	1600	1580	1550	Total	1460	1350	1250	Total
Cloud Forest Species								
Reynoldsia pleiosperma	60%	18%	49%	42%	0	0	0	
Spiraeanthemum samoense	7%	0%	27%	11%	0	0	0	
Coprosma strigulosa	5%	18%	5%	9%	0	0	0	
Glochidion christophersenii	6%	2%	2%	3%	0	+	0	
Weinmannia affinis	1%	0%	8%	3%	0	0	0	
Elattostachys falcata?	4%	2%	1%	2%	0	0	0	
Pittosporum samoense	0%	7%	0%	2%	0	1	1	
Scaevola nubigena	2%	0%	+	1%	0	0	0	
Totals	**85%**	**47%**	**92%**	**77%**				
Cloud/Montane Forest Species								
Dysoxylum huntii	9%	42%	1%	17%	29	51	74	51%
Homalanthus acuminatus	0%	5%	0%	2%	31	7	2	13%
Cyathea spp.	+	0%	5%	2%	3	1	8	4%
Geniostoma rupestre	1%	+	+	1%	1	1	1	1%
Totals	**10%**	**47%**	**6%**		**64%**	**60%**	**83%**	
Montane Forest Species								
Hedycarya denticulata	0	0	0		13	13	0	9%
Schefflera samoensis	+	0	0		5	6	10	7%
Macaranga reineckei	0	0	0		10	9	0	6%
Syzygium patentinerve	1	0	0		4	5	+	3%
Totals					**32%**	**33%**	**10%**	

During the survey, three 500 m^2 plots in montane forest were sampled—at 1,450, 1,350, and 1,250 m elevation. Additionally, a checklist of species present was made in the area above the car park at 1,000 to 1,050 m elevation. The data from these plots is shown in Appendix 1.2. A summary of the data, combined with that of the cloud forest plots, is shown in Table 1.1 above.

The montane forest, when mature, has a high dense canopy with large trees, the majority of which are *Dysoxylum huntii*. However, during a severe disturbance, such as a cyclone (Samoa was hit by two severe cyclones in the early 1990s), the large trees are often blown down, leaving the formerly shaded forest floor exposed to the sun. This increase in sunlight allows for the germination and growth of species that would otherwise not be able to become established. The trees that benefit from these disturbances, many of them classified as "secondary forest trees" often grow rapidly and soon after the cyclone they are the dominant species. However, as the forest ages, the typical montane forest trees (often called primary forest trees) gradually reassert their dominance. The secondary forest trees gradually disappear, as they are unable to reproduce in the forest shade, and after several decades, the montane forest will again be dominated by primary forest species. This is the cycle of plant succession that is part of tropical ecology. Trees that dominate the canopy are called canopy trees; trees somewhat smaller and often with their crowns below the canopy are subcanopy trees; and small trees up to perhaps 8 m in height are called understory trees.

The relative dominance of trees in the three cloud forest and three montane forest plots is shown in Table 1.2. The trees here are divided into cloud forest species (the top group of eight species), montane forest species (the bottom group of four), and species found in both communities (the middle group of 4). The dominant montane forest species in the three montane forest plots is shown in the far right column. *Dysoxylum huntii* is by far the dominant species in the montane forest, with 51% relative dominance—more than 5 times the amount of the second most dominant tree. The other species, in descending order of relative dominance, are *Homalanthus acuminatus* (fogāmamala, 9%), *Hedycarya denticulata* (9%), *Schefflera samoensis* (7%), *Macaranga reineckei* (6%), *Cyathea* spp. (several species of oliolī, 4%), *Syzygium patentinerve* (3%), and *Geniostoma rupestre* (tāipoipo). Of these, *Dysoxylum huntii* and *Homalanthus acuminatus* are canopy species; *Hedycarya denticulata* and *Syzygium patentinerve* are probably subcanopy trees; *Schefflera samoensis*, *Macaranga reineckei*, and *Cyathea* spp. are probably subcanopy secondary forest species; and *Geniostoma rupestre* is an understory tree. The first two plots are relatively undisturbed with many large trees and a shady forest floor, but the 1,250 m elevation plot is relatively disturbed, judging by the much smaller number of trees, especially of large trees (less than half of each compared to that recorded in the two higher-elevation plots).

The forest floor of the montane forest is dominated by shade-loving ferns and, to a lesser extent, seedlings of the component tree species. At the higher elevations, *Blechnum doodioides* and *Blechnum vulcanicum* are among the dominant species, but these gradually disappear with decreasing elevation, and were not found in the 1,250 m elevation plot. Showing the opposite pattern is *Lomagramma cordipinna*, which was the dominant ground cover species at the lower elevation plot (1,250 m), but was a minor species at the highest elevation plot (1,460 m). Likewise, the king fern *Angiopteris evecta* (gase) was absent from the higher two plots, but increases in abundance with decreasing elevation from the 1,250 m level. Other common species include *Diplazium harpeodes*, *Diplazium dilatatum*, *Dennstaedtia* cf. *flaccida*, *Asplenium feejeense*, and *Leptopteris wilkesiana*. Epiphytic orchids are probably more common than was recorded, because these are often missed, as they typically grow up in the canopy where they are not noticeable.

The tree trunks in montane forest are often also dominated by fern species. One in particular, *Lomagramma cordipinna*, dominates tree trunks, where they become fertile, but they also dominate the forest floor, where they are sterile. Other common epiphytic fern species include *Phymatosorus powellii*, *Nephrolepis pseudolauterbachii*, *Arthropteris repens*, *Asplenium horridum*, and *Oleandra neriiformis*. Terrestrial orchids are uncommon, and in fact, no orchid was found in more than one of the three montane forest plots. Vines are not as common as at lower elevations. Two basic types of vines are present in montane forest—trunk climbers and lianas. The most common trunk climbers are the aroid *Rhaphidophora graeffei*, and three relatives of the screwpines—*Freycinetia storckii*, *Freycinetia reineckei*, and *Freycinetia hombronii*. Lianas are less common (and more difficult to see), but the most frequently encountered species are *Embelia vaupelii*, *Faradaya amicorum*, *Mucuna glabra*, and *Strongylodon* sp. *nova*. The latter two were recorded only at the lower elevation of montane forest (below 1,250 m).

Table 1.2. Tree relative dominance (%) in past and present plots in Savai'i cloud forest.

Plot Number[1]	1	2	3	4	5	6	7	Average
1. *Reynoldsia pleiosperma*	19	65	47	0	60	49	18	37%
2. *Spiraeanthemum samoense*	44	12	15	19	7	27	3	18%
3. *Dysoxylum huntii*	8	5	5	35	9	1	42	15%
4. *Coprosma strigulosa*	7	5	8	6	5	5	18	5%
5. *Glochidion christophersenii*	1	2	5	14	6	2	2	5%
6. *Weinmannia affinis*	0	6	9	0	1	8	0	3%
7. *Pittosporum samoense*	1	0	4	5	0	0	7	2%
8. *Homalanthus acuminatus*	9	0	0	1	0	0	5	2%
9. *Streblus anthropophagorum*	5	0	0	8	+	0	+	2%
10. *Elattostachys falcata*	+	+	3	0	4	1	2	1%
11. *Hernandia moerenhoutiana*	1	0	1	8	0	0	0	1%
12. *Cyathea* spp.	+	1	0	0	+	5	+	1%
13. *Geniostoma rupestre*	2	1	+	+	1	+	+	1%
14. *Scaevola nubigena*	1	0	1	0	2	+	0	1%
15. *Hedycarya denticulata*	1	0	0	2	1	0	0	1%
16. *Coriaria ruscifolia*	0	2	1	0	0	+	0	+
17. *Wikstroemia foetida*	0	0	0	0	2	1	0	+
18. *Metrosideros collina*	0	1	0	0	1	0	0	+
19. *Meryta* cf. malietoa	+	0	+	0	0	0	+	+

[1] Current Plots: 1=Silisili (1,600 m); 2=Mauga Mū (1,500 m); and 3=Mata o le Afi (1,600 m). Plots from previous publications: 4=Silisili (1,700 m); 5=Near Silisili (1,580 m); 6=Mata ole Afi (1,500 m); and 7=Mauga Mū (1,600 m).

4.5. Cloud Forest

The cloud forest community is found at the highest elevation on Savai'i. It imperceptibly blends into montane forest at it lower boundary, which, based upon the data and delineation of the vegetation communities during the present study, can be placed at about 1,500 m elevation. During the daytime, the upper slopes of the island are usually cloaked in clouds. The warm, moist trade winds ascend the mountains and cool down, causing the condensation of water into clouds and rain, making the climate of the cloud forest decidedly cool and damp. Frost has been observed at 1,550 m elevation in the winter (Whistler, pers. obs., 1996), so the temperature can approach freezing at times. The rainfall is also high, but no data is available to confirm this. While rainfall generally increases with increasing elevation, it probably decreases above a certain high elevation, possibly caused by the presence of a temperature inversion layer (a layer of warmer air overlying cooler air) that, if present, effectively limits the moist air from reaching the summit of the island. Such a temperature inversion layer is present in Hawaii 50–70% of the time, starting at 1,600 m elevation (Wagner *et al.* 1990).

The forest is low in stature compared to the rainforest at lower elevations, with the trees mostly less than 15 m in height (except *Reynoldsia pleiosperma*). The cool, moist conditions promote the profusion of epiphytes (Fig. 1.7) that sometimes grow so thickly that tree trunks appear twice their actual diameter. The canopy is usually continuous (when not disturbed by cyclones), but is not as dense as in undisturbed rainforest (Fig. 1.8). The cool temperatures in the cloud forest account for the presence of certain temperate genera, such as *Weinmannia* (Cunoniaceae), *Vaccinium* (Ericaceae), *Ascarina* (Chloranthaceae), and *Coriaria* (Coriariaceae) that extend to the higher-elevation forest of Samoa. The cloud forest is virtually untouched by man because it is too remote, too wet, and too cool to be used by the villagers. The only visitors are the occasional pig hunters.

Figure 1.7. Open canopy cloud forest with dense epiphytic growth (Photo by A. Whistler).

Figure 1.8. Cloud forest canopy at Mata o le Afi showing emergent *Reynoldsia* trees in the canopy (Photo by A. Whistler).

The differences between the flora of montane and cloud forest on Savai'i can be seen in Table 1.1, which shows the data from the three montane forest and three cloud forest plots. The biggest flora difference between the two communities is the dominance of *Reynoldsia pleiosperma* (vī vao). In the three plots sampled during the current study, it had a 42% relative dominance. Other species that are common in cloud forest but virtually absent at lower elevation are *Spiraeanthemum samoense*, *Coprosma strigulosa*, *Glochidion christophersenii*, *Pittosporum samoense*, and *Scaevola nubigena*. (*Elattostachys falcata* is also on the list of cloud forest species, but it was common all the way down to near sea level.) The second group of plants in Table 1.1 comprises species that are found in both montane and cloud forest. The most conspicuous of these is *Dysoxylum huntii* (maota mea), which is dominant tree of montane forest, and is probably second in overall dominance in cloud forest. The species diversity of cloud forest is probably not as high as that of the adjacent montane forest, but there is a higher rate of endemism (50% of the species in Table 1.2). Most have no Samoan names, since few tree species in the interior of large high islands were likely to be used for timber or other purposes and, consequently, have not been given local names.

To make a larger sample size, the cloud forest plot data from the present study (three plots) is combined with data from four plots sampled in previous surveys (Whistler 1978; Schuster *et al*. 1999). This table shows the dominance of *Reynoldsia pleiosperma*, which was found in six of the seven plots and was dominant in four of them. Although it does not prevail in numbers, the scattered individual trees reach a huge size (Fig. 1.9). Only 21 of the 361 trees (6%) in the three cloud forest plots shown in Appendix 1.2 were this species, but the average relative dominance of was 42%. *Reynoldsia* begins as an epiphyte and sends its roots down from the host tree (probably mostly *Dysoxylum huntii*) to the ground. They apparently eventually become "stranglers," comparable to the banyan trees *Ficus obliqua* and *Ficus prolixa* (both called āoa) or *Fagraea berteroana* (pualulu) of lower elevations, and may completely surround and destroy the host tree as they attain a large size (Fig. 1.9). Because of this habit and their high elevation habitat, they are of no use for timber.

Figure 1.9. Large *Reynoldsia* tree at Mata o le Afi (Photo by A. Whistler).

The two other dominant species cloud forest trees shown in Table 1.2 are *Dysoxylum huntii* and *Spiraeantheum samoense*. *Dysoxylum* was dominant in two of the seven plots, *Spiraeanthemum* in one. It is likely that *Dysoxylum* dominates the canopy of undisturbed cloud forest, with scattered *Reynoldsia* rising above the canopy as "emergent" species (Fig. 1.9). *Spiraeanthemum* probably dominates cloud forests that have recently been damaged by cyclones. The other canopy trees shown in Table 1.2 are *Homalanthus acuminatus* (fogāmamala), *Hernandia moerenhoutiana* (pipi), *Elattostachys falcata*, *Metrosideros collina*, and *Weinmannia affinis*. The other trees in Table 1.2 are subcanopy and understory species, including *Streblus anthropophagorum*, *Coprosma strigulosa*, *Meryta malietoa* (lau fagufagu), *Glochidion christophersenii*, *Geniostoma rupestre* (tāipoipo), *Hedycarya denticulata*, and *Pittosporum samoense*. *Scaevola nubigena* and *Wikstroemia foetida* (fau mū), and another plant not shown on the list, *Coriaria ruscifolia*, are more shrubby in habit. At least four species of tree fern (*Cyathea* spp.) occur in this forest, but they were not distinguished from each other in the surveys. This includes *Cyathea medullaris*, *Cyathea decurrens*, *Cyathea affinis*, and *Cyathea whitmeei*. One large endemic palm occurs here too, *Clinostigma vaupelii* (niu vao). Its crowns can be seen growing above the canopy on some of the volcanic cones in the area. Other less common species not shown in Table 1.2 include *Ascarina diffusa*, *Schefflera samoensis*, *Syzygium patentinerve*, and *Xylosma samoense*, all of them characteristic of cloud and montane forest.

Epiphytes are abundant in cloud forest, particularly orchids, ferns, and mosses. The number of orchids in the cloud forest is probably less than in the montane and lowland forest, but at least 15 epiphytic Samoan orchids are known to occur at over 1,500 m elevation on Savai'i. Epiphytes are typically most common in the canopy, but they are often missed during botanical surveys. They can most easily be seen on trees or shrubs in the volcanic scrub community. At least 27 species of epiphytic ferns occur in forest above 1,500 m in elevation, 21 of which were found during the present survey. Perhaps the most common and conspicuous epiphyte is the lily *Collospermum samoense*, which sometimes covers trees with its long, narrow, silvery leaves. Other non-fern, non-orchid epiphytes include two small herbs, *Peperomia rechingerae* and *Peperomia reineckei*.

The forest floor of cloud forest is dominated by relatively large, shade-loving ferns. The most common species are *Blechnum procerum*, *Blechnum doodioides*, *Blechnum vulcanicum*, *Athyrium oosorum*, and *Dicksonia brackenridgei*. Other less common species recorded during the present survey include *Ophioglossum reticulatum*, *Asplenium feejeense*, and *Asplenium horridum.* A dozen or so other terrestrial ferns are also known from this elevation of Savai'i, but were not found during the present survey (several of them were found in the Schuster *et al*. 1999 survey). Much less common are terrestrial orchids, several of which were recorded in the plots—*Calanthe triplicata*, *Calanthe ventilabrum*, *Phaius flavus*, *Chrysoglossum ornatum*, *Liparis stricta*, and *Liparis phyllocardia*. Several dicot herbs are sometimes common on the forest floor, especially at least two endemic species of *Elatostema*. The most common shrub in cloud forest is the kava relative *Macropiper timothianum*. *Vaccinium whitmeei* sometimes grows in open-canopy forest, often appearing to be an epiphyte as well as growing on the ground. The scrambling shrub *Alyxia stellata* (gau) is sometimes found here.

Lianas and trunk climbers are of relatively minor significant in the cloud forest. Only about five species of liana were recorded in there during the present survey—*Alyxia* cf. *bracteolosa*, *Hoya filiformis*, *Zehneria mucronata*, *Embelia vaupelii*, and *Jasminum didymum*. Several other liana species are known from this elevation, but were not found in the cloud forest during this trip. The only trunk climbers recorded from this elevation belong to the genus *Freycinetia* ('ie'ie), but only one of them, *Freycinetia storckii*, was found in the cloud forest during the present study.

5. THE FLORA

The flora of the montane region of Savai'i, i.e., the area above 1,000 m, comprises numerous species of angiosperms, ferns, and fern allies (collectively called "vascular plants)." The area sampled during the present study is only a corridor that runs along the 4-wheel drive road and bulldozer track from A'opo village to Mata o le Afi, and along the walking trails eastward to Mauga Silisili. The plants recorded during the survey (Appendix 1.1) by no means comprise a complete sampling of the montane flora of the island, since many species known to be present there were not found. Presumably, most of the species not found during the present study occur at the lower elevations, i.e., mostly in montane rather than cloud forest on the island. The six vegetation plots set up during the present study extended down only to 1,250 m elevation (although a checklist was done at the area above the car park at 1,000 to 1,050 m elevation).

The vascular flora recorded during the study numbered 235 species, as shown in Appendix 1.1. The 114 dicot species can be divided into endemic species (56), indigenous species (45), and alien species (13). The 48 monocot species also comprise endemic species (15), indigenous species (29), and alien species (4). The rate of endemism (endemic species/native species) of the vascular species is 49% (71/145), which is considerably higher than the overall rate of angiosperm endemism in Samoa (ca. 30%). This is to be expected since there is a positive correlation between the rate of endemism and elevation. The ferns were represented by 73 species recorded during the survey, eight of them endemic, 65 of them indigenous, and none of them alien. This rate of endemism (9%) is near the average for Samoa.

Nearly all of the species recorded during the survey were previously known from Samoa, with the exception of two "new" species. One is an orchid in the genus *Calanthe*, a single clump or population of which was found on the edge of the bulldozer track (and which would have been destroyed if the bulldozer track was a meter wider on that side) at Mauga Mū. This appears to a species new to science (P. Cribb, pers. comm.) and is not found in the book on the orchid flora of Samoa (Cribb and Whistler 1996). The other "new" species is an orchid in the genus *Bulbophyllum*. It may be been collected once before in a sterile state, but it is either a new record for Samoa or a new species. Duplicate specimens of both have been sent to the orchid expert Cribb for further study.

Only 17 alien (introduced species) were recorded during the survey. This is significant because the number of alien species in an area is a good indicator of disturbance. The 17 alien species include several that were restricted to the middle and sides of the 4-wheel drive track and the bulldozer track beyond it. This includes the typical weeds *Crassocephalum crepidioides*, *Emilia sonchifolia* (flora's paint brush, fua lele), *Erechtites valerianifolia* (fua lele), *Stictocardia tiliifolia*, *Kyllinga polyphylla* (Navua sedge), *Hyptis pectinata* (comb hyptis), *Physalis peruviana* (cape gooseberry), *Eleusine indica* (goosegrass, ta'ata'a), and *Solanum americanum* (black nightshade, magalo). All of these are modern introductions, with the exception of *Solanum americanum*, which is apparently a Polynesian introduction. Only three weedy species, *Clidemia hirta* (Koster's curse), *Mikania micrantha* (mile-a-minute vine), and *Paspalum conjugatum* (T-grass, vao lima), were recorded in the native forest plots, but the first two of these extended only up to 1,050 and 1,250 m elevation, respectively, and the latter one was found all the way up to 1,650 m elevation. *Bidens pilosa* (beggar's tick) was seen only once, on a lava flow, so its presence in the study area was inconsequential. The three tree species found in the montane forest—*Endiandra elaeocarpa*, *Elaeocarpus ulianus*, and *Syzygium samarangense* (nonu vao)—appear to be timber trees that were introduced in the last century or so and which have become naturalized and indistinguishable from native tree species. (Some of the species names in the earlier surveys have been recently corrected.)

Only five native vascular plant species recorded during the 1996 survey (Schuster *et al*. 1999) were not found during the present survey—*Peperomia samoensis* and four fern species. Only four native flowering plants recorded during the 1975 survey (Whistler 1978) above 1,300 m elevation were not found during the present survey—two of them small herbaceous plants in the same genus (*Elatostema*), and the other two (*Carex maculata* and *Nertera granadensis*) occur in a habitat that was not sampled during the present survey (*Carex* bog). (The ferns were not listed in the latter report). Approximately 160 vascular plant species have been reported to occur in Samoa above 1,500 m elevation (Whistler, pers. notes). About 75% of these were found during the present survey. It is likely that several more new species might be found with further surveys in the montane and cloud forest of Savai'i, especially in eastern area of the uplands.

6. DISCUSSION

Although logistic problems, illness, and inclement weather limited the area that could be studied during the present expedition, much useful information was nevertheless obtained. This is particularly true of the cloud forest, which was defined here as the area above 1,500 m elevation. There is no distinct boundary between cloud forest and montane forest, but based upon six plots that were sampled, the main difference between the two is the presence and dominance of *Reynoldsia pleiosperma* in the former. When the plot data from this survey is combined with that obtained during previous surveys (Whistler 1978; Schuster *et al*. 1999), Reynoldsia was shown to be present in six of the seven plots, and dominant in four of them. It is not clear if this difference between the two communities can be maintained if further surveys are done in the large area of cloud and montane forest to the east that could not sampled this time. Although the tree was not recorded in montane forest plots sampled in Schuster 1999, it is known to occur down to about 320 m elevation, but not in the sampled plots. The montane forest above 1,000 m elevation is much larger than the cloud forest on Savai'i, and has a much greater biodiversity. It is this area between 800 and 1,500 m elevation that needs the most future work.

The flowering plant species found during the present survey of the area above 1,000 m on Savai'i numbered 145, which represents about 26 percent of the flowering plant flora of Samoa. A much wider survey of this area above 1,000 m elevation, beyond the confines of the A'opo to Mauga Silisili corridor, would yield a much larger number. Since the upland area that should be protected probably extends down to at least 800 m elevation, probably at least half of all native flowering plants known from Samoa occur in Upland Savai'i. The same can be said for the ferns of the archipelago.

A survey of the rare plants of Samoa (Whistler 2010) produced 108 plant species that were deemed as rare in the country. Sixteen of these were reported to occur in the montane to cloud forest above 1,000 m elevation on Savai'i (Table 1.3). (Some of the other 108 species also probably also occur there, but their collection data was lacking elevation information). Six of the sixteen were found during the present survey: *Trichosanthes reineckeana*, *Abutilon whistleri*, *Peperomia pallida, Psychotria bristolii*, *Chrysoglossum ornatum*, and *Spiranthes sinensis*. At least three of these should probably not be considered as rare in Samoa. *Abutilon whistleri* was occasional in two plots, and is probably just a species that was under-collected because of its high elevation habitat rather than actual rarity. The same can probably be said for *Peperomia pallida*, which is frequent as an epiphyte on trees in the montane forest, and *Chrysoglossum ornatum*, which is occasional as a terrestrial orchid in cloud forest.

Table 1.3. Rare flowering plants reported to occur above 1,000 m elevation on Savai'i (Whistler 2010)

Species	Family	Expedition Results
Trichosanthes reineckeana Cogn.	Cucurbitaceae	Found once on trailside
Abutilon whistleri Fosb.	Malvaceae	Occasional in montane forest
Metrosideros gregoryi Christoph.	Myrtaceae	Not found
Syzygium vaupelii Whistler	Myrtaceae	Not found
Peperomia pallida (Forst. f.) Dietr.	Piperaceae	Common in montane forest
Psychotria bristolii Whistler	Rubiaceae	Found once in montane forest
Psychotria juddii Christoph.	Rubiaceae	Not found
Melicope sulcata T. G. Hartley	Rutaceae	Not found
Bulbophyllum pachyanthum Schltr.	Orchidaceae	Not found
Bulbophyllum trachyanthum Kraenzl.	Orchidaceae	Not found
Chrysoglossum ornatum Bl.	Orchidaceae	Occasional in cloud forest
Cryptostylis arachnites (Bl.) Hassk.	Orchidaceae	Not found
Peristylus tradescantifolius (Rchb. f.) Kores	Orchidaceae	Not found
Schoenorchis micrantha Reinw. ex Bl.	Orchidaceae	Not found
Spiranthes sinensis (Pers.) Ames	Orchidaceae	Found twice on ash plane
Freycinetia reineckei Warb.	Pandanaceae	Not found

It appears that the montane and cloud forests have largely recovered from the extensive damage of the two cyclones that hit the island two decades ago (Val and Ofa). These two storms did extensive damage to the forest, and probably blew down the majority of the large trees. Some areas appear to have been damaged more than others. The ones probably receiving the least damage are those dominated by *Dysoxylum huntii*, which, with the exception of *Reynoldsia pleiosperma*, is the dominant species of the whole area above 1,000 m (and down to 800 m or below). Forests with fewer large trees, and those dominated by tree species having tiny seeds (e.g., *Spiraeanthemum samoense*) are probably in a state of transition (plant succession) that will probably eventually result in a forest dominated by the *Dysoxylum huntii* (along with *Reynoldsia pleiosperma* at the higher elevations).

One sign of health is the relative absence of alien weedy species. The three most aggressive alien weeds of montane Savai'i are probably *Mikania micrantha* (fue saina, mile-a-minute vine), *Clidemia hirta* (Koster's curse), and *Paspalum conjugatum* (vao lima, T-grass). Of these, only the *Paspalum* was found in the cloud forest. The maximum elevation recorded for the *Mikania* was 1,050 m elevation (although it has been recorded as rare in cloud forest in earlier surveys) and for *Clidemia*, 1,250 m. *Clidemia* is sometimes found in shady forest, but the other two species are mostly restricted to sunny, trailside areas. *Solanum americanum* (magalo) is also common, but is probably an ancient Polynesian introduction to Samoa. It is mostly restricted to the now-being-overgrown bulldozer track and 4-wheel drive road (Fig 1.10). The overall dominant of this disturbance is *Euphorbia reineckei*, which is strangely an endemic species (the vast majority of weeds in Samoa are alien species). Several other weedy species were recorded from the study area, but these are minor and restricted mostly to the road and track.

The vegetation of the montane area of Savai'i above 1,000 m (and probably above 800 m or lower) appears to be in good shape. Most of it is returning to high-canopy forest after the devastating cyclones. Very few alien species have become established in the area, and those that have are restricted mostly to the road and track leading up to Mata o le Afi (Fig 1.10). The whole area receives extensive rainfall, which percolates down to the coast, where it is flows into the ocean in wells and springs. If the vegetation is removed or damaged in this area, this ability to absorb the rainfall will decrease, leading to more rapid run off, leading to flooding, and less water reaching the coast, leading to water shortages for Savai'i's villages. It is imperative that this area be preserved by all possible means, especially when damage to it is combined with unpredictable climate changes that almost certainly will affect Samoa.

Figure 1.10. Bulldozer track at the base of Mata o le Afi (Photo by A. Whistler).

7. RECOMMENDATIONS

Based upon the present field study, several recommendations can be made.

1. EXTEND THE MONTANE SAVAI'I BOTANICAL SURVEY

Because of all the problems that cropped up during the expedition, only a fraction of the upland area above 1,000 m elevation was studied. More botanical surveys and more plots are needed to give a more complete picture of Upland Savai'i. Nearly all of the detailed, modern plot data is from the same area as visited by the expedition: there is virtually nothing from the eastern portion of the Upland Savai'i, e.g., around Lake Mafane and Lake Mataulano.

2. ENFORCE EXISTING LAWS

Laws are in place to regulate timber cutting in Samoa. However, logging still occurs on Savai'i despite the absence of logging permits. It is sometimes difficult to reconcile differences of opinion between local land owners and the government, making protection of the native forests problematic. Although laws are on the books, they are often not enforced. The bulldozer road up to Mata o le Afi is illegal and potentially devastating to the area, as it opens up an avenue for the introduction of new weeds to the area. The road is the biggest threat to the integrity of Upland Savai'i.

3. PROTECTION OF THE WHOLE AREA

The whole upland area above 800 m elevation or lower should be given official protection. This is a very difficult goal, because the villagers around the island are unaware of how important the area is as a watershed and for its biodiversity. The island of Savai'i has been rated as the 23rd most important island in the South Pacific in terms of its conservation value. The area is remote and infrequently visited, so the biggest threat is the currently existing (but deteriorating) road and future plantation roads. With new roads comes logging and the establishment of temporary plantations, leading to irreparable harm to the environment.

4. EDUCATION

The importance of Upland Savai'i for its biodiversity and watershed value should be the focus of an education program in schools and to the public. The MNRE should embark on a programme that highlights the great importance of the upland area of the island.

5. FLORA OF SAMOA

Money was recently allocated to the production of a flora of Samoa, but has since been reallocated to other activities. No complete checklist or flora exists, and only one person has been working on it. If the project is not done soon, all the information gathered over the last forty years may be lost. The flora should go along with a biodiversity survey of Samoa's forests because just knowing what plants occur in Samoa is not enough. Their range in Samoa and possibly rarity should also be known.

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Appendix 1.1. Checklist of vacular plants recorded in the study area (above 1000 m)

Species	Author	Status	Name	Voucher
DICOTS				
Acanthaceae				
Dicliptera samoensis	Seem.	E		---
Amaranthaceae				
Cyathula prostrata	(L.) Bl.	I		12888
Apocynaceae				
Alstonia pacifica	(Seem.) A. C. Smith	I		12942
Alyxia cf. *braceolosa*	Rich	E	lau maile	---
Alyxia stellata	(Forst.) Roemer & Schultes	I	gau	---
Araliaceae				
Meryta cf. *malietoa*	Cox	I	ma'ulu'ulu	---
Reynoldsia pleiosperma	A. Gray	E	vī vao	12945
Schefflera samoensis	(A. Gray) Harms	E		12904
Asclepiadaceae				
Hoya filiformis	Rechinger	E	fue sele lā	12790
Tylophora samoensis	A. Gray	I		---
Asteraceae				
Adenostemma viscosum	Forst.	I		12901
Bidens pilosa	L.	X		12842
Crassocephalum crepidioides	(Benth.) S. Moore	X		---
Emilia sonchifolia	(L.) DC.	X	pua lele	12783
Erechtites valerianifolia	(Wolf) DC.	X		---
Mikania micrantha	H. B. K.	X	fue saina	---
Chloranthaceae				
Ascarina diffusa	A. C. Smith	I		---
Convolvulaceae				
Stictocardia tiliifolia	(Desr.) Hall. f.	X		12887
Coriariaceae				
Coriaria ruscifolia	L.	I		12796
Cucurbitaceae				
Trichosanthes reineckeana	Cogn.	E		12886
Zehneria grayana	(Bl.) Miq.	I		---
Cunoniaceae				
Spiraeanthemum samoense	A. Gray	E		12845
Weinmannia affinis	A. Gray	I		12843
Ebenaceae				
Diospyros major	(Forst. f.) Bakh.	I		12895
Elaeocarpaceae				
Elaeocarpus floridanus	Hemsley	I	a'amati'e	---
Elaeocarpus tuasivicus	Christoph.	E		12917
Elaeocarpus ulianus	Christoph.	X		---

Species	Author	Status	Name	Voucher
Ericaceae				
Vaccinium whitmeei	F. Mueller	E		lost
Euphorbiaceae				
Bischofia javanica	Bl.	I	ʻoʻa	---
Claoxylon echinospermum	Muell. Arg.	I		12834
Euphorbia reineckei	Pax	E		12884
Glochidion christophersenii	Croizat	E		12836
Glochidion ramiflorum	Forst.	I	masame	---
Homalanthus acuminatus	(Muell. Arg.) Pax	E		12908
Homalanthus nutans	(Forst. f.) Guillemin	I	fogā mamala	lost
Macaranga monostyla	Whistler	E		12952
Macaranga reineckei	Pax ex Reinecke	E		12927
Fabaceae				
Mucuna glabra	(Rein.) Wilmot-Dear	I	fue inu	---
Strongylodon sp. nova		I		---
Flacourtiaceae				
Xylosma samoense	Sleumer	E		12924
Gentianaceae				
Fagraea berteroana	A. Gray ex Benth.	I	pua lulu	---
Gesneriaceae				
Cyrtandra auranticarpa	Gillette	E		12935
Cyrtandra nitens	C. B. Clarke	E		12794
Cyrtandra richii	A. Gray	E		12745
Goodeniaceae				
Scaevola nubigena	Lauterb.	E		lost
Hernandiaceae				
Hernandia moerenhoutiana	Guillemin	I	pipi	---
Icacinaceae				
Citronella samoensis	(A. Gray) Howard	I		---
Medusanthera samoensis	(Reinecke) Howard	E	matamō	---
Lamiaceae				
Hyptis pectinata	(L.) Poiret	X		12902
Lauraceae				
Cryptocarya samoensis	Christoph.	E		12892
Cryptocarya turbinata	Gillespie	E		12934
Endiandra elaeocarpa	Gillespie	X		---
Loganiaceae				
Geniostoma rupestre	Forst.	I	tāipoipo	12876
Loranthaceae				
Amyema artensis	(Mont.) Danser	I	tapuna	12928
Malvaceae				

Species	Author	Status	Name	Voucher
Abutilon whistleri	Fosb.	E		12933
Melastomaceae				
Clidemia hirta	(L.) D. Don	X		---
Melastoma denticulatum	Labill.	I	fua lole	---
Meliaceae				
Aglaia samoensis	A. Gray	I?		---
Dysoxylum huntii	Merr.	E	maota mea	---
Monimiaceae				
Hedycarya denticulata	(A. Gray) Perk. & Gilg	E		12865
Moraceae				
Ficus godeffroyi	Warb.	E		12866
Ficus hygrophila	Rechinger	E		---
Ficus samoensis	Summerh.	E		12896
Ficus uniauriculata	Warb.	E		12883
Streblus anthropophagorum	(Seem.) Corner	I		---
Myrsinaceae				
Embelia vaupelii	Mez	E		---
Rapanea longipes	A. C. Smith	E		12870
Myrtaceae				
Metrosideros collina	A. Gray	I		---
Syzygium patentinerve	Christoph.	E		12937
Syzygium inophylloides	(A. Gray) C. Muell.	I	asi toa	---
Syzygium samarangense	(Bl.) Merr. & Perry	X	nonu vao	---
Oleaceae				
Jasminum didymum	Forst. f.	I		---
Passifloraceae				
Passiflora aurantia	Forst. f.	I		lost
Piperaceae				
Macropiper puberulum	Benth.	I	'ava'avaaitu	12954
Macropiper timothianum	A. C. Smith	I	'ava'avaaitu	12879
Peperomia lonchophylla	C. DC.	E		12890
Peperomia cf. *pallida*	(Forst. f.) Dietr.	I?		12894
Peperomia rechingerae	C. DC.	E		12808
Peperomia reineckei	C. DC.	E		12807
Piper rechingeri	C. DC.	E	'ava'avaaitu	12889
Pittosporaceae				
Pittosporum samoense	Christoph.	E		---
Rhamnaceae				
Alphitonia zizyphoides	(Spreng.) A. Gray	I	toi	---
Rubiaceae				
Calycosia sessilis	A. Gray	E		---
Coprosma Savai'iensis	Rechinger	E		12816
Coprosma strigulosa	Lauterb.	E		12798

Species	Author	Status	Name	Voucher
Ixora samoensis	A. Gray	I?	filofiloa	12936
Nertera granadensis	(Mutis ex L. f.) Druce	I		---
Psychotria bristolii	Whistler	E		---
Psychotria christophersenii	Whistler	E		12803
Psychotria closterocarpa	A. Gray	E		---
Psychotria gigantopus	K. Schum.	E		lost
Psychotria grandistipulata	(Lauterb.) Whistler	E		---
Psychotria insularum	A. Gray	I	matalafi	12944
Psychotria pacifica	K. Schum.	E		12863
Psychotria samoana	K. Schum.	E		12885
Psychotria vaupelii	Whistler	E		12878
Sarcopygme pacifica	(Rein.) Setchell & Christoph.	E	‘u‘unu	---
Rutaceae				
Melicope lauterbachii	T.G. Hartley	E		12914
Melicope Savai'iensis	T.G. Hartley	E		12940
Sapindaceae				
Elattostachys falcata	(A.Gray) Radlk.	I	taputo‘i	---
Sapotaceae				
Palaquium stehlinii	Christoph.	E	gasu	---
Planchonella samoensis	H. J. Lam ex Christoph.	I	māmālava	---
Solanaceae				
Physalis peruviana	L.	X		lost
Solanum americanum	Mill.	X	magalo	12899
Thymelaeaceae				
Wikstroemia foetida	(L. f.) A. Gray	I		lost
Ulmaceae				
Trema cannabina	Lour.	I	magele	---
Urticaceae				
Boehmeria virgata	(Forst. f.) Guillemin	I		lost
Cypholophus macrocephalus	Wedd.	E		---
Elatostema basiandrum	Reinecke	E		12831
Elatostema cupreo-viride	Rechinger	E		12812
Pipturus samoensis	(Hochreut.) Skottsb.	E		lost
Procris pedunculata	(Forst.) Wedd.	I	fua lole	---
Verbenaceae				
Faradaya amicorum	Seem.	I	mamalupe	---
Violaceae				
Melicytus samoensis	(Christoph.) A. C. Smith	I		12925
MONOCOTS				
Agavaceae				
Cordyline fruticosa	(L.) Chev.	I	tī	---
Araceae				
Rhaphidophora graeffei	Engl.	E		---

Species	Author	Status	Name	Voucher
Arecaceae				
Balaka tuasivica	Christoph.	E	māniuniu	12891
Clinostigma vaupelii	(Burr.) Burr.	E	niu vao	---
Cyperaceae				
Carex graeffeana	Boeck.	I		12822
Kyllinga polyphylla	Willd. ex Kunth	X		12782
Mariscus cyperinus	(Retz.) Vahl	I?		12859
Heliconiaceae				
Heliconia laufao	Kress	E		---
Joinvilleaceae				
Joinvillea cf. *adscendens*	Gaud. ex Brongn. & Gris.	I		12949
Liliaceae				
Collospermum samoense	Skottsb.	E		12860
Musaceae				
Musa X paradisiaca	L.	I	taemanu	---
Orchidaceae				
Bulbophyllum betchei	F. Muell.	E		12926
Bulbophyllum cf. *pallidum*	Schltr.	E?		12775
Calanthe triplicata	(Willemet) Ames	I		12853
Calanthe ventilabrum	Rchb. f.	E		12820
Calanthe sp. nova		E		12786
Chrysoglossum ornatum	Bl.	I		12810
Coelogyne lycastoides	F. Muell. and Kraenzl.	I		12861
Dendrobium biflorum	Schltr.	I		---
Dendrobium mohlianum	Rchb. f.	I		12777
Dendrobium reineckei	Schltr.	E		12774
Dendrobium vagans	Schltr.	E		12792
Earina valida	Rchb. f.	I		---
Epiblastus sciadanthus	(F. Muell.) Schltr.	I		12795
Eria robusta	(Bl.) Lindl.	I		12778
Eria rostriflora	Rchb. f.	I		12848
Erythrodes oxyglossa	Schltr.	I		---
Glomera montana	Rchb. f.	I		---
Habenaria samoensis	F. Muell. & Kraenzl.	E		12913
Liparis layardii	F. Muell.	I		12841
Liparis phyllocardia	Schltr.	E		---
Mediocalcar paradoxum	(Kraenzl.) Schltr.	I		12851
Phaius flavus	(Bl.) Lindl.	I		12800
Phreatia micrantha	(A. Rich.) Schltr.	I		---
Oberonia equistans	(Forst. f.) Mutel	I		12791
Spathoglottis plicata	Bl.	I		12858
Spiranthes sinensis	(Pers.) Ames	I		12918
Pandanaceae				

Species	Author	Status	Name	Voucher
Freycinetia hombronii	Mart.	E		lost
Freycinetia reineckei	Warb.	E		---
Freycinetia storckii	Seem.	I?		12849
Poaceae				
Cenchrus echinatus	L.	X	vao tuitui	12956
Cyrtococcum oxyphyllum	Stapf	I		---
Eleusine indica	(L.) Gaertn.	X	ta'ata'a	12900
Imperata cylindrica	(L.) P. Beauv.	I		12797
Microstegium glabratum	(Brongn.) A. Camus	I?		12741
Oplismenus compositus	(L.) P. Beauv.	I?	sefa	12818
Paspalum conjugatum	Bergius	X	vao lima	12817
Paspalum orbiculare	Forst. f.	I		---
FERNS				
Angiopteridaceae				
Angiopteris evecta	(Forst. f.) Hoffman	I	gahe	---
Aspidiaceae				
Tectaria decurrens	(Presl) Copeland	I		12880
Aspleniaceae				
Asplenium cf. *cuneatum*	Lam.	I		12837
Asplenium excisum	Presl	I		12882
Asplenium feejeense	Brackenridge	I		12874
Asplenium horridum	Kaulf.	I		12796
Asplenium insiticum	Brackenridge	I		12784
Asplenium laserpitiifolium	Lam.	I		---
Asplenium lobulatum	Mett.	I		12799
Asplenium multifidum	Brackenridge	I		12826
Asplenium nidus	L.	I	laugapāpā	12824
Asplenium tenerum	Forst. f.	I		12907
Athyriaceae				
Athyrium oosorum	(Baker) Christ	E		12780
Diplazium dilatatum	Bl.	I		---
Diplazium echinatum	Christensen	I		12781
Diplazium harpeodes	Moore	I		12864
Blechnaceae				
Blechnum doodioides	(Brackenridge) Brownlie	I		12827
Blechnum orientale	L.	I		12931
Blechnum procerum	(Forst. f.) Swartz	I		12829
Blechnum vulcanicum	(Bl.) Kuhn	I		12929
Cyatheaceae				
Cyathea affinis	(Forst. f.) Sw.	I	oliolī	12785
Cyathea alta	Copeland	I	oliolī	12946
Cyathea decurrens	(Hook.) Copeland	I	oliolī	12839

Species	Author	Status	Name	Voucher
Cyathea lunulata	(Forst. f.) Copeland	I	oliolī	---
Cyathea medullaris	(Forst. f.) Sw.	I	oliolī	
Cyathea vaupelii	Copeland	E	oliolī	12911
Cyathea whitmeei	Baker	I	oliolī	12811
Davalliaceae				
Davalllia plumosa	Baker	E		12921
Davallia solida	(Forst.) Sw.	I	laugasēsē	12838
Humata serrata	Brackenridge	I		12846
Dennstaediaceae				
Dennstaedtiacf. flaccida	(Forst. f.) Bernhardi	I		12867
Dicksoniaceae				
Dicksonia brackenridgei	Mett.	I		12915
Elaphoglossaceae				
Elaphoglossum Savai'iense	(Baker) Diels	E		12813
Gleicheniaceae				
Dicranopteris linearis	(Burm.) Underwood	I		12787
Grammitidaceae				
Ctenopteris contigua	(Forst. f.) Holttum	I		12805
Ctenopteris tenuisecta	(Bl.) S. Sm.	I		12804
Grammitis insularis	Copeland	E		12943
Scleroglossum sulcatum	(Kuhn) van Alderwerelt	I		12856
Hemionitidaceae				
Coniogramme fraxinea	(Don) Diels	I		12872
Hymenophyllaceae				
Hymenophyllum flabellatum	Labill.	I		12852
Hymenophyllum imbricatum	Bl.	I		12801
Trichomanes apiifolium	Presl	I		12871
Trichomanes bipunctatum	Poiret	I		
Trichomanes maximum	v. d. Bosch	I		12939
Hypolepidaceae				
Histiopteris incisa	(Thunb.) J. Sm.	I		12779
Lomariopsidaceae				
Bolbitis palustris	(Brackenridge) Hennipman	I		---
Lomagramma cordipinna	Holttum	I		12881
Loxogrammaceae				
Loxogramme parksii	Copeland	I		12819
Nephrolepidaceae				
Arthropteris repens	(Brackenridge) Christensen	I		12947
Nephrolepis hirsutula	(Forst. f.) Presl	I	vao tua niu	12793
Nephrolepis pseudolauterbachii	Miyamoto	I		12847
Oleandraceae				
Oleandra neriiformis	Cav.	I		12922

Species	Author	Status	Name	Voucher
Oleandra sibbaldii	Grev.	I		12843
Ophioglossaceae				
Ophioglossum reticulatum	L.	I		12814
Osmundaceae				
Leptopteris wilkesiana	(Brackenridge) Christ	I		---
Polypodiaceae				
Belvisia vaupelii	(Christensen) Copel.	E		12840
Drynaria rigidula	(Sw.) Beddome	I		12955
Phymatosorus commutatus	(Bl.) Pichi Serm.	I		12950
Phymatosorus nigrescens	(Bl.) Pichi Serm.	I		---
Phymatosorus powellii	(Baker) Pichi Serm.	I		12832
Polypodium subauriculatum	Bl.	I		12951
Selliguea feeoides	Copeland	I		12835
Pteridaceae				
Pteris tripartita	Sw.	I		12905
Thelypteridaceae				
Sphaerostephanos reineckei	(Christensen) Holttum	E		12930
Vittariaceae				
Antrophyum subfalcatum	Brackenridge	I		12869
Vittaria elongata	Sw.	I		12875
FERN ALLIES				
Lycopodiaceae				
Lycopodium carinatum	Desv. ex Poiret	I		---
Lycopodium cernuum	L.	I		12788
Lycopodium phlegmaria	L.	I		12957
Lycopodium phyllanthum	Hook. & Arn.	I		12923
Lycopodium venustulum	Gaud.	I		12789
Lycopodium verticillatum	L.	I		12920
Selaginellaceae				
Selaginella whitmeei	Baker	E		12825

Appendix 1.2. Tree relative dominance in 500 m² montane and cloud forest plots

Site	Species	No. Trees	No. >15 cm	Basal Area	Rel. Dom.
Site 1	**Silisili Track Cloud Forest (1580 m).**		**13.610189S**	**172.505492W**	
1	*Reynoldsia pleiosperma*	6	4	14552	60%
2	*Dysoxylum huntii*	40	4	2249	9%
3	*Spiraeanthemum samoense*	10	3	1789	7%
4	*Glochidion christophersenii*	9	4	1551	6%
5	*Coprsma strigulosa*	8	2	1373	5%
6	*Elattostachy falcata*	8	3	1099	4%
7	*Wikstroemia foetida*	12	1	455	2%
8	*Scaevola nubigena*	3	2	452	2%
9	*Metrosideros collina*	3	0	297	1%
10	*Weinmannia affinis*	1	0	227	1%
11	*Hedycarya denticulata*	2	0	167	1%
12	*Geniostoma rupestre*	2	0	159	1%
13	*Hernandia moerenhoutiana*	1	0	133	1%
14	*Cyathea whitmeei*	1	0	113	+
15	*Streblus anthropophagorum*	1	0	28	+
	Totals	**107**	**23**	**24644**	**100%**
Site 2	**Mata o le Afi Cloud Forest (1550 m).**		**13.607062S**	**172.504638W**	
1	*Reynoldsia pleiosperma*	7	6	9796	49%
2	*Spiraeanthemum samoense*	38	16	5499	27%
3	*Weinmannia affinis*	19	4	1622	8%
4	*Coprosma strigulosa*	8	3	1085	5%
5	*Cyathea affinis*	6	2	979	5%
6	*Glochidion christophersenii*	8	0	395	2%
7	*Dysoxylum huntii*	7	0	200	1%
8	*Wikstroemia foetida*	2	0	143	1%
9	*Elattostachys falcata*	3	0	108	1%
10	*Scaevola nubigena*	2	0	76	+
11	*Coriaria ruscifolia*	1	0	64	+
12	*Cyathea decurrens*	1	0	38	+
13	*Meryta* cf. *malietoa*	1	0	20	+
14	*Geniostoma rupestre*	1	0	20	+
	Totals	**104**	**31**	**20045**	**100%**
Site 3	**Mauga Mū Cloud Forest (1600 m).**		**13.608425S**	**172.513172W**	
1	*Dysoxylum huntii*	89	19	11785	42%
2	*Reynoldsia pleiosperma*	8	8	4928	18%
3	*Coprosma strigulosa*	2	2	4889	18%

Site	Species	No. Trees	No. >15 cm	Basal Area	Rel. Dom.
4	*Pittosporum samoense*	13	6	1933	7%
5	*Homalanthus acuminatus*	13	5	1492	5%
6	*Spiraeanthemum samoense*	7	2	731	3%
7	*Glochidion christophersenii*	4	2	679	2%
8	*Elattostachys falcata*	6	0	462	2%
9	*Syzygium patentinerve*	1	1	314	1%
10	*Cyathea sp.*	1	0	95	+
11	*Meryta* cf. *malietoa*	2	0	88	+
12	*Schefflera samoensis*	2	0	56	+
13	*Streblus anthropophagorum*	1	0	50	+
14	*Geniostoma rupestre*	1	0	50	+
15	*Medusanthera samoense*	1	0	28	+
16	*Ficus* cf. *hygrophila*	1	0	28	+
	Totals	**152**	**45**	**27608**	**100%**
Site 4	**Mauga Mū Motane Forest (1460 m).**		**13.602305S**	**172.520373W**	
1	*Homalanthus acuminatus*	32	20	7898	31%
2	*Dysoxylum huntii*	33	8	7405	29%
3	*Hedycarya denticulata*	42	4	3147	13%
4	*Macaranga* cf. *reinecki*	12	7	2433	10%
5	*Schefflera samoensis*	18	1	1373	5%
6	*Syzygium patentinerve*	6	3	976	4%
7	*Cyathea* sp.	5	3	720	3%
8	*Abutilon whistleri*	1	1	314	1%
9	*Ficus* cf. *godeffroyi*	3	0	330	1%
10	*Geniostoma christophersenii*	3	0	212	1%
11	*Pittosporum samoense*	1	0	113	+
12	*Streblus anthropophagorum*	2	0	99	+
13	*Merya* cf. *malietoa*	1	0	64	+
14	*Medusanthera samoense*	1	0	64	+
15	*Citronella samoense*	1	0	38	+
16	*Melicope lauterbachii*	1	0	20	+
	Totals:	**162**	**47**	**25206**	**100%**
Site 5	**Upper A'opo Uta Motane Forest (1350 m).**		**13.597417S**	**172.525569W**	
1	*Dysoxylum huntii*	17	9	15644	51%
2	*Hedycarya denticulata*	38	6	3995	13%
3	*Macaranga* cf. *reineckei*	10	8	2773	9%
4	*Homalanthus acuminatus*	15	4	2089	7%

Site	Species	No. Trees	No. >15 cm	Basal Area	Rel. Dom.
5	*Schefflera samoensis*	26	2	1750	6%
6	*Syzygium patentinerve*	8	3	1549	5%
7	*Rapanea* cf. *longipes*	2	1	1041	3%
8	*Abutilon whistleri*	2	2	592	2%
9	*Geniostoma rupestre*	6	0	439	1%
10	*Pittosporum samoense*	3	1	342	1%
11	*Cyathea* sp.	1	1	283	1%
12	*Medusanthera samoense*	3	0	193	1%
13	*Psychotria* sp.	1	0	50	+
14	*Hernandia moerenhoutiana*	1	0	50	+
15	*Glochidion* cf. *christophersenii*	2	0	40	+
	Totals:	**135**	**37**	**30830**	**100%**
Site 6	**Lower A'opo Uta Motane Forest (1250 m).**		**13.593047S**	**172.532051W**	
1	*Dysoxylum huntii*	8	8	23022	74
2	*Schefflera samoensis*	37	5	3102	10
3	*Cyathea* sp. no. 1	7	3	1768	6
4	*Homalanthus acuminatus*	2	1	665	2
5	*Rapanea* cf. *longipes*	1	1	572	2
6	*Cyathea* sp. no. 2	5	1	495	2
7	*Geniostoma rupestre*	3	1	441	1
8	*Sarcopygme pacifica*	5	1	440	1
9	*Glochidion* cf. *ramiflorum*	1	0	362	1
10	*Syzygium patentinerve*	2	0	151	+
11	*Psychotria vaupelii*	3	0	104	+
12	*Melicytus samoensis*	1	0	92	+
13	*Hedycarya denticulata*	1	0	38	+
14	*Elaeocarpus tuasivicus*	1	0	38	+
15	*Psychotria* sp.	1	0	38	+
16	*Musa* X *paradisiaca*	1	0	38	+
	Totals:	**79**	**20**	**31366**	**100%**

Appendix 1.3. Tree relative dominance in previous cloud forest studies

	Species	No. Trees	No. >15 cm	Basal Area	Rel. Dom.
1. Silisili Track Cloud Forest Plot (1600 m plus) from Whistler (1975).					
1	*Spiraeanthemum samoense*	38	21	37220	44%
2	*Reynoldsia pleiosperma*	2	2	16345	19%
3	*Homalanthus acuminatus*	2	2	7698	9%
4	*Dysoxylum huntii*	12	9	6915	8%
5	*Coprosma Savai'iense*	19	10	6122	7%
6	*Streblus anthropophagorum*	7	7	4544	5%
7	*Geniostoma rupestre*	8	3	1451	2%
8	*Psychotria christophersenii*	6	1	537	1%
9	*Scaevola nubigena*	2	2	498	1%
10	*Glochidion christophersenii*	4	1	466	1%
11	*Pittosporum samoense*	5	1	464	1%
12	*Hedycarya denticulata*	3	1	451	1%
13	*Hernandia moerenhoutiana*	1	1	430	1%
14	*Cyathea* sp.	1	1	227	+
15	*Cyrtandra aurantiicarpa*	3	0	241	+
16	*Melicope lauterbachii*	4	0	140	+
17	*Meryta* cf. *malietoa*	2	0	114	+
18	*Elattostachys falcata*	1	0	38	+
	Totals	**120**	**62**	**83901**	**100%**
2. Mauga Mū Cloud Forest Plot (1500 m) from Schuster *et al*. (1999).					
1	*Reynoldsia pleiosperma*	18	17	28851	65%
2	*Spiraeanthemum samoense*	30	13	5277	12%
3	*Weinmannia affinis*	8	3	2468	6%
4	*Dysoxylum huntii*	28	2	2108	5%
5	*Coprosma strigulosa*	12	4	2071	5%
6	*Glochidion christophersenii*	11	2	815	2%
7	*Coriaria ruscifolia*	2	2	743	2%
8	*Geniostoma rupestre*	11	0	437	1%
9	*Cyathea medullaris?*	2	0	288	1%
10	*Coprosma Savai'iense*	1	1	285	1%
11	*Metrosideros collina*	2	0	247	1%
12	*Elattostachys falcata*	2	0	210	+
13	*Wikstroemia foetida*	3	0	117	+
14	*Cyathea sp.*	1	0	96	+
15	*Syzygium patentinerve*	1	0	38	+
16	*Schefflera samoensis*	1	0	28	+
	Totals	**133**	**44**	**44079**	**100%**

	Species	No. Trees	No. >15 cm	Basal Area	Rel. Dom.
3. Mata o le Afi Cloud Forest Plot (1560 m plus) from Schuster *et al*. (1999).					
1	*Reynoldsia pleiosperma*	16	14	20279	47%
2	*Spiraeanthemum samoense*	29	17	6593	15%
3	*Weinmannia affinis*	14	8	3879	9%
4	*Coprosma strigulosa*	18	11	3285	8%
5	*Glochidion christophersenii*	25	2	2152	5%
6	*Dysoxylum huntii*	34	0	1964	5%
7	*Pittosporum samoense*	14	3	1582	4%
8	*Elattostachys falcata*	8	1	1238	3%
9	*Scaevola nubigena*	3	1	601	1%
10	*Hernandia moerenhoutiana*	1	1	417	1
11	*Coriaria ruscifolia*	4	0	390	1
12	*Citronella samoense*	1	1	208	+
13	*Meryta malietoa*	1	0	96	+
14	*Geniostoma rupestre*	1	0	38	+
15	*Cyrtandra nitens*	1	0	20	+
	Totals	**170**	**59**	**42742**	**100%**
4. Silisili Cloud Forest Plot (1700 m plus) from Schuster *et al*. (1999).					
1	*Dysoxyum huntii*	55	6	4711	35%
2	*Spiraeanthemum samoense*	6	5	2532	19%
3	*Glochidion christophersenii*	8	4	1832	14%
4	*Streblus anthropophagorum*	5	2	1077	8%
5	*Hernandia moerenhoutiana*	1	1	855	8%
6	*Coprosma strigulosa*	7	1	834	6%
7	*Pittosporum samoense*	7	0	713	5%
8	*Hedycarya denticulata*	3	1	302	2%
9	*Elaeocarpus tuasivicus*	2	0	188	1%
10	*Homalanthus acuminatus*	4	0	170	1%
11	*Coprosma Savai'iense*	1	0	50	+
12	*Claoxylon echinatum*	1	0	38	+
13	*Geniostoma rupestre*	1	0	38	+
	Totals	**101**	**20**	**13340**	**100%**

Appendix 1.4. Checklist of the Species Found in the Seven Plots

Family	Species Elevation (m)	1600	1550	1590	1460	1350	1250	1050
	DICOTS							
Acanthaceae	*Dicliptera samoensis*	--	--	--	--	--	--	X
Amaranthaceae	*Cyathula prostrata*	--	--	--	--	--	--	X
Apocynaceae	*Alstonia pacifica*	--	--	X	X	--	--	--
Apocynaceae	*Alyxia* cf. *bracteolosa*	X	--	X	X	X	--	X
Apocynaceae	*Alyxia stellata*	X	--	--	--	--	--	--
Araliaceae	*Meryta* cf. *malietoa*	X	X	X	X	--	--	X
Araliaceae	*Reynoldsia pleiosperma*	X	X	X	--	--	--	--
Araliaceae	*Schefflera samoensis*	--	X	X	X	X	X	X
Asclepiadaceae	*Hoya filiformis*	X	--	--	--	X	X	--
Asteraceae	*Adenostemma viscosum*	--	X	--	--	--	--	--
Asteraceae	*Mikania micrantha*	--	--	--	--	--	--	X
Chloranthaceae	*Ascarina diffusa*	--	X	--	--	--	--	--
Coriariaceae	*Coriaria ruscifolia*	--	X	--	--	--	--	--
Cucurbitaceae	*Zehneria mucronata*	--	X	--	--	--	X	X
Cunoniaceae	*Spiraeanthemum samoense*	X	X	X	X	--	--	--
Cunoniaceae	*Weinmannia affinis*	X	X	--	--	--	--	--
Ebenaceae	*Diospyros major*	--	--	--	--	--	--	X
Elaeocarpaceae	*Elaeocarpus floridanus*	--	--	--	--	--	--	X
Elaeocarpaceae	*Elaeocarpus tuasivicus*	--	--	--	--	X?	--	--
Elaeocarpaceae	*Elaeocarpus ulianus*	--	--	--	--	--	X	X
Ericaceae	*Vaccinium whitmeei*	X	X	--	--	--	--	--
Euphorbiaceae	*Bischofia javanica*	--	--	--	--	--	--	X
Euphorbiaceae	*Euphorbia reineckei*	--	X	--	--	--	--	--
Euphorbiaceae	*Glochidion christophersenii*	X	X	X	X	--	--	--
Euphorbiaceae	*Glochidion ramiflorum*	--	--	--	--	X?	X	X
Euphorbiaceae	*Homalanthus acuminatus*	--	--	X	X	X	X	X
Euphorbiaceae	*Homalanthus nutans*	--	--	--	--	--	--	X
Euphorbiaceae	*Macaranga monostyla*	--	--	--	X	--	X	X
Euphorbiaceae	*Macaranga reineckei*	--	--	--	X?	X	X	--
Fabaceae	*Mucuna glabra*	--	--	--	--	--	X	X
Fabaceae	*Strongylodon* sp. nova	--	--	--	--	--	--	X
Gesneriaceae	*Cyrtandra auranticarpa*	--	X	--	X	X	--	--
Gesneriaceae	*Cyrtandra richii*	--	--	--	--	--	--	X
Goodeniaceae	*Scaevola nubigena*	X	X	--	--	--	--	--
Hernandiaceae	*Hernandia moerenhoutiana*	X	--	--	X	X	X	X
Icacinaceae	*Citronella samoensis*	--	--	--	X	X	--	--
Icacinaceae	*Medusanthera samoensis*	--	X	X	X	--	--	--

Family	Species Elevation (m)	1600	1550	1590	1460	1350	1250	1050
Lauraceae	*Cryptocarya samoensis*	--	--	--	--	--	--	X
Lauraceae	*Cryptocarya turbinata*	--	--	--	X	X	--	X
Lauraceae	*Endiandra elaeocarpa*	--	--	--	--	--	--	X
Loganiaceae	*Geniostoma rupestre*	X	X	X	--	--	X	X
Malvaceae	*Abutilon whistleri*	--	--	--	X	X	--	--
Melastomaceae	*Clidemia hirta*	--	--	--	--	--	X	X
Melastomaceae	*Melastoma denticulatum*	--	--	X	--	--	--	--
Meliaceae	*Aglaia samoensis*	--	--	--	--	--	--	X
Meliaceae	*Dysoxylum huntii*	X	X	X	X	X	X	X
Monimiaceae	*Hedycarya denticulata*	X	X	X?	X	X	X	X
Moraceae	*Ficus godeffroyi*	--	--	X	X?	--	X	X
Moraceae	*Ficus hygrophila*	X	X	--	--	--	--	--
Moraceae	*Ficus samoensis*	--	--	--	--	--	--	X
Moraceae	*Ficus uniauriculata*	--	--	--	--	--	X	X
Moraceae	*Streblus anthropophagorum*	X	X	X	--	X	--	X
Myrsinaceae	*Embelia vaupelii*	--	--	--	--	--	--	X
Myrsinaceae	*Rapanea longipes*	--	--	--	--	X	X	X
Myrtaceae	*Metrosideros collina*	X	--	--	--	--	--	--
Myrtaceae	*Syzygium patentinerve*	--	--	X	X	X	X	X
Myrtaceae	*Syzygium inophylloides*	--	--	--	--	--	--	X
Myrtaceae	*Syzygium samarangense*	--	--	--	--	--	--	X
Oleaceae	*Jasminum didymum*	X	--	X	--	--	--	X
Piperaceae	*Macropiper timothianum*	X	X	X	X	X	X	X
Piperaceae	*Peperomia lonchophylla*	--	--	--	--	--	X	X
Piperaceae	*Peperomia* cf. *pallida*	--	--	--	--	--	X	X
Piperaceae	*Peperomia rechingerae*	X	X	--	X	--	--	--
Piperaceae	*Peperomia reineckei*	X	--	--	X	X	--	--
Piperaceae	*Piper rechingeri*	--	--	--	--	--	--	X
Pittosporaceae	*Pittosporum samoense*	X	X	X	X	X	--	X
Rhamnaceae	*Alphitonia zizyphoides*	--	--	--	--	--	X	X
Rubiaceae	*Calycosia sessilis*	--	--	--	--	--	--	X
Rubiaceae	*Coprosma strigulosa*	X	X	X	--	--	--	--
Rubiaceae	*Ixora samoensis*	--	--	--	X	--	--	X
Rubiaceae	*Psychotria christophersenii*	X	X	X	--	--	--	--
Rubiaceae	*Psychotria closterocarpa*	--	--	--	X	X	--	--
Rubiaceae	*Psychotria grandistipulata*	--	--	--	--	--	--	X
Rubiaceae	*Psychotria insularum*	--	--	X	X	--	--	X
Rubiaceae	*Psychotria pacifica*	--	--	--	X	X	X	X
Rubiaceae	*Psychotria samoana*	--	--	--	--	--	X	X
Rubiaceae	*Psychotria vaupelii*	--	--	--	--	X	X	X

Family	Species Elevation (m)	1600	1550	1590	1460	1350	1250	1050
Rubiaceae	*Sarcopygme pacifica*	--	--	--	X	X	X	X
Rutaceae	*Melicope lauterbachii*	X	X	X	X	--	--	--
Rutaceae	*Melicope Savai'iensis*	--	--	--	X	--	--	--
Sapindaceae	*Elattostachys falcata*	X	X	X	--	X	--	--
Sapotaceae	*Palaquium stehlinii*	--	--	--	--	--	--	X
Sapotaceae	*Planchonella samoensis*	--	--	--	--	--	--	X
Thymelaeaceae	*Wikstroemia foetida*	X	X	--	--	--	--	--
Ulmaceae	*Trema cannabina*	--	--	--	--	--	X	X
Urticaceae	*Boehmeria virgata*	--	--	--	--	--	--	X
Urticaceae	*Cypholophus macrocephalus*	--	--	--	--	--	--	X
Urticaceae	*Elatostema basiandrum*	X	X	--	X	X	--	--
Urticaceae	*Elatostema cupreo-viride*	X	X	--	X	X	--	X
Urticaceae	*Procris pedunculata*	--	--	--	--	--	X	--
Verbenaceae	*Faradaya amicorum*	--	--	X	--	--	--	X
Violaceae	*Melicytus samoensis*	X	X	--	X	X	X	--
	MONOCOTS							
Araceae	*Rhaphidophora graeffei*	--	--	X	X	X	X	X
Arecaceae	*Balaka tuasivica*	--	--	--	--	X	--	--
Arecaceae	*Clinostigma vaupelii*	X	--	X	--	X	--	--
Heliconiaceae	*Heliconia laufao*	--	--	--	--	--	--	X
Joinvilleaceae	*Joinvillea* cf. *adscendens*	--	--	--	--	--	X	--
Liliaceae	*Collospermum samoense*	X	X	X	X	X	X	X
Musaceae	*Musa X paradisiaca*	--	--	--	--	--	X	X
Orchidaceae	*Bulbophyllum* cf. *pallidum*	X	--	--	--	--	--	--
Orchidaceae	*Calanthe triplicata*	--	X	--	--	--	--	--
Orchidaceae	*Calanthe ventilabrum*	--	X?	--	--	--	--	--
Orchidaceae	*Chrysoglossum ornatum*	X	--	--	--	--	--	--
Orchidaceae	*Coelogyne lycastoides*	X	--	--	--	--	--	X
Orchidaceae	*Dendrobium biflorum*	--	--	--	--	--	--	X
Orchidaceae	*Dendrobium mohlianum*	X	X	--	--	--	--	--
Orchidaceae	*Earina valida*	--	--	--	--	--	--	X
Orchidaceae	*Eria robusta*	--	X	--	--	--	--	--
Orchidaceae	*Erythrodes oxyglossa*	--	--	--	--	--	--	X?
Orchidaceae	*Habenaria samoensis*	--	--	X	X	--	--	--
Orchidaceae	*Liparis layardii*	X	X	--	X	X	--	--
Orchidaceae	*Liparis phyllocardia*	X	--	--	--	--	--	--
Orchidaceae	*Mediocalcar paradoxum*	--	X	--	--	--	--	--
Orchidaceae	*Phaius flavus*	X?	X?	--	--	--	--	--
Orchidaceae	*Phreatia micrantha*	--	--	--	--	--	--	X
Pandanaceae	*Freycinetia hombronii*	--	--	--	X	X	--	--

Family	Species Elevation (m)	1600	1550	1590	1460	1350	1250	1050
Pandanaceae	*Freycinetia reineckei*	--	--	--	X?	--	--	X
Pandanaceae	*Freycinetia storckii*	--	X	--	--	--	--	--
Poaceae	*Cyrtococcum oxyphyllum*	X	X	--	X	--	--	--
Poaceae	*Microstegium glabratum*	--	--	--	--	--	--	X
Poaceae	*Oplismenus compositus*	--	--	--	--	--	--	X
Poaceae	*Paspalum conjugatum*	--	--	--	--	--	--	X
	FERNS	--						
Angiopteridaceae	*Angiopteris evecta*	--	--	--	--	--	X	X
Aspidiaceae	*Tectaria decurrens*	--	--	--	--	--	--	X
Aspleniaceae	*Asplenium* cf. *cuneatum*	--	--	X	--	X	--	X
Aspleniaceae	*Asplenium excisum*	--	--	--	--	--	--	X
Aspleniaceae	*Asplenium feejeense*	--	--	X	--	X	--	X
Aspleniaceae	*Asplenium horridum*	--	X	X	X	--	X	X
Aspleniaceae	*Asplenium laserpitiifolium*	--	--	--	--	--	X	X
Aspleniaceae	*Asplenium lobulatum*	--	--	--	X	--	X	--
Aspleniaceae	*Asplenium multifidum*	X?	X	--	X	X	--	--
Aspleniaceae	*Asplenium nidus*	X	X	--	X	--	X	X
Aspleniaceae	*Asplenium tenerum*	--	--	--	--	--	X	X
Athyriaceae	*Athyrium oosorum*	X	X	--	--	--	--	--
Athyriaceae	*Diplazium dilatatum*	--	--	--	X	X	X	X
Athyriaceae	*Diplazium echinatum*	--	--	--	--	--	X	X
Athyriaceae	*Diplazium harpeodes*	--	--	--	X	X	X	X
Blechnaceae	*Blechnum doodioides*	--	--	X	X	X	--	X
Blechnaceae	*Blechnum procerum*	X	X	--	--	--	--	--
Blechnaceae	*Blechnum vulcanicum*	X	X		X	X		
Cyatheaceae	*Cyathea affinis*	--	X	--	--	--	--	--
Cyatheaceae	*Cyathea alta*	--	--	--	--	X	--	--
Cyatheaceae	*Cyathea decurrens*	--	X	--	--	--	--	--
Cyatheaceae	*Cyathea lunulata*	--	--	--	--	--	--	X
Cyatheaceae	*Cyathea whitmeei*	X	--	--	--	--	--	--
Davalliaceae	*Davalllia plumosa*	--	X	--	--	--	--	--
Davalliaceae	*Humata serrata*	--	X	--	X?	--	--	--
Dennstaediaceae	*Dennstaedtia* cf. *flaccida*	--	--	X	X	X	X	X
Dicksoniaceae	*Dicksonia brackenridgei*	--	X	X?	--	--	X?	X?
Elaphoglossaceae	*Elaphoglossum Savai'iense*	X	X	--	--	--	--	--
Grammitidaceae	*Ctenopteris contigua*	X	X	--	--	X	X	--
Grammitidaceae	*Ctenopteris tenuisecta*	X	X	--	X	--	--	--
Grammitidaceae	*Grammitis insularis*	--	X	--	--	--	X	--
Grammitidaceae	*Scleroglossum sulcatum*	--	X	--	--	--	--	--
Hemionitidaceae	*Coniogramme fraxinea*	--	--	--	X	X	X	X

Family	Species Elevation (m)	1600	1550	1590	1460	1350	1250	1050
Hymenophyllaceae	*Hymenophyllum flabellatum*	--	X	--	X	X	--	X?
Hymenophyllaceae	*Hymenophyllum imbricatum*	X	X	--	--	--	--	--
Hymenophyllaceae	*Trichomanes apiifolium*	--	--	--	X	--	--	--
Hymenophyllaceae	*Trichomanes bipunctatum*							X
Hymenophyllaceae	*Trichomanes maximum*	--	--	--	--	X	X	X?
Hypolepidaceae	*Histiopteris incisa*	--	--	--	X	--	X	--
Lomariopsidaceae	*Bolbitis palustris*	--	--	--	--	--	X	X
Lomariopsidaceae	*Lomagramma cordipinna*	--	--	--	X	X	X	X
Loxogrammaceae	*Loxogramme parksii*	X	X	--	--	X	--	--
Nephrolepidaceae	*Arthropteris repens*	--	--	--	X	X	--	X
Nephrolepidaceae	*Nephrolepis pseudolauterbachii*	X	X	X	X	X	X	X
Oleandraceae	*Oleandra neriiformis*	--	--	--	--	--	X	X
Ophioglossaceae	*Ophioglossum reticulatum*	--	X	--	X	--	--	--
Osmundaceae	*Leptopteris wilkesiana*	--	--	X	--	X	X	X
Polypodiaceae	*Belvisia vaupelii*	--	X	--	X	--	X	X
Polypodiaceae	*Drynaria rigidula*	--	--	--	--	--	--	X
Polypodiaceae	*Phymatosorus commutatus*	--	--	--	--	--	X	X
Polypodiaceae	*Phymatosorus powellii*	X	X	--	X	X	X	X
Polypodiaceae	*Polypodium subauriculatum*	--	--	--	--	--	X	X
Polypodiaceae	*Selliguea feeoides*	X	X	--	--	--	--	--
Pteridaceae	*Pteris tripartita*	--	--	--	--	--	--	X
Thelypteridaceae	*Sphaerostephanos reineckei*	--	--	--	X?	X	--	--
Vittariaceae	*Vittaria elongata*	--	--	--	--	--	X?	X
	FERN ALLIES							
Lycopodiaceae	*Lycopodium phlegmaria*	--	--	--	X	--	X?	--
Lycopodiaceae	*Lycopodium verticillatum*	X	X	--	X	--	--	--

CHAPTER 2
Report on the reptiles of Upland Savai'i

ROBERT FISHER (USGS) AND MOEUMU UILI (MNRE), REPTILE SURVEY LEADERS

Team Members: Timoteo Moresi (DOF-MNRE), Fialelei Enoka (DEC-MNRE), Finau Masoe and Tanielu Tipa (DOF – MNRE, Savai'i).

1. SUMMARY

The reptile team conducted a 21 kilometre transect from the coast east of Asau to the uplands ending near Mauga Silisili at over 1720 m elevation. This transect covered the main habitats on Savai'i and allowed the team to determine where various reptile species and invasive species occurred across this elevational gradient. No previous reptile research had taken place on Savai'i above the elevation of A'opo Village. Limited sampling was also done around the Forestry Station in Asau.

The team detected 11 species of lizards during these surveys, which is the majority of species known from Samoa. Noticeably absent was the Pacific black skink (*Emoia nigra*), which is a dominant element of the Samoan lizard fauna. Also no individuals of the Pacific boa (Candoia bibroni) were detected despite the concentrated effort spent looking for them. One boa was detected by the avifauna team at their Site 1, by the TV tower on a log in a marsh. The invasive house gecko (*Hemidactylus frenatus*) was also not detected along the main transect, but was the most abundant gecko on buildings in Asau.

No reptiles were found above 1320 m elevation and most species were found significantly below there. Snake-eyed skinks (*Cryptoblepharus poecilopleurus*) were detected on Savai'i for the first time at Asau Getaway Resort then above the sawmill on the way to A'opo. Since western Savai'i is so poorly known for reptiles, this is the first time many of these species were recorded from this part of the island.

Surveys for invasive species detected mammalian species (cats, rats, and pigs) and invertebrate species (Yellow Crazy ants and Big-headed ants). The mammals were found at various sites along the transect, including high elevations. The ants were found at lower elevations along the transect, but the Yellow Crazy ants appear to be irrupting currently on Savai'i and were swamping our traps from sea level to 500 m elevation.

The low elevation lizard occurrences from sea level to 500 m appeared impaired by the invasive ants. Although habitat looked good in many places along the transect, certain species were rare or absent when the invasive ants were present, e.g. the Samoan skink (*Emoia samoensis*) which only occurred at elevations higher than the ants, whereas elsewhere in its range it occurs down to sea level.

Currently the uplands over 500 m are free of invasive ants. We know from Hawai'i that invasive ants occur to over 2,000 m elevation and are ecologically very destructive to native flora and fauna. There is an immediate need to try to stop this upward ant invasion to protect this at-risk ecosystem, and to study the intact system now prior to an invasion.

2. INTRODUCTION

The significance of the survey was to try to identify hidden diversity that had not been recorded from Samoa previously. Reptiles are poorly represented in the literature on Samoa, especially Savai'i (Gill 1993). Previous work has been done in some parts of the Samoan islands but no formal survey had been done on Savai'i, and no quantitative surveys have been done previously anywhere in Samoa for reptiles. The Samoa Biodiversity Survey and Action Plan (Government of Samoa 2001) did not define conservation action(s) for reptiles because at the time there was insufficient data on them. The outcome of this survey can be used to assess current conditions of existing reptiles now, for comparison in the future and to strengthen recommendations for active protocols to improve the status of biodiversity in Upland Savai'i and to develop strategies to govern protection from unsustainable uses, which pose threats to the survival of native species critical to sustaining Samoa's biodiversity.

The lizards of Savai'i are the most poorly known in all of Samoa, including American Samoa. No previous survey work had been done inland of the road that circumnavigates the island.

The primary goals for the BIORAP reptile surveys were the following:

1. Determine the reptile fauna of the uplands of Savai'i.
2. Determine the elevational limits of reptiles along the Savai'i elevational gradient.
3. Determine the distribution and abundance of invasive species along the Savai'i elevational gradient.

3. OBJECTIVES

Primary objective: to provide as much data as possible to update the list of terrestrial reptiles for Samoa.

Secondary objective: to identify threats to reptiles and causes of any declines and make management recommendations.

Previously Gill (1993) summarized the known data for terrestrial reptiles from Samoa. He included data from museum records, his own trip to Samoa, and both trips made by Fisher (1988, 1990). Zug and Ineich conducted a trip to Samoa in 1992 and the data from that trip has not been published yet, but incudes records from Savai'i, although like the other previous expeditions, it only includes low elevation sites. Prior to the BIORAP, Savai'i remained the largest island in the central Pacific with the least amount of information known about its reptiles. No previous quantitative sampling had been done which could serve as baseline for comparison to these surveys.

Threats to the reptile fauna of Savai'i include habitat destruction, but also invasive species. In particular in sites where native habitat persists, invasive species would be the greatest risk factors. The most significant invasive species that threaten reptiles in Samoa are cats, rats, centipedes, and ants. Our surveys included these species as covariates to help understand our findings for the reptiles.

Overview of Study Design

We conducted field surveys for reptiles and ants, primarily Yellow Crazy Ants (YCA), from sea level in the forestry tract-lava flow area east of Asau to near Mauga Silisili, the highest point in Samoa (Figure 2.1). The majority of the time spent surveying the transects was conducted on foot; this ensured that all locations along the transect were surveyed well. Despite weather and time constraints, a few additional pairs of eyes helped ease the search for existing reptiles. Overall more than 21 kilometres of transects were run from 0 m elevation to over 1750 m elevation. These surveys covered a broad variety of habitats on Savai'i, from coastal lava fields (Figure 2.2) through disturbed secondary forests and plantations to high montane forests.

Figure 2.1. Location of reptile survey stations. s

Figure 2.2. Lava flow habitat at low elevation towards the end of the survey transect (Photo by R. Fisher).

Figure 2.3. Reptile team at beach end of mountain to coast transect (Photo by R. Fisher).

4. METHODS AND SITE DESCRIPTION

Survey Team (Figure 2. 3)

Our team consisted of the following members:

Robert Fisher (Co-team leader; USGS) – entire survey

Moeumu Uili (Co-team leader; DEC-MNRE) – entire survey

Timoteo Moresi (DOF-MNRE) – entire survey

Fialelei Enoka (DEC-MNRE) – lower elevations only

Finau Masoe and Tanielu Tipa (DOF –MNRE, Savai'i) – lower elevations only

Methodology

Surveys consisted of three elements:

1. The design of the survey was conducted using transects that sampled the different types of ecosystems in the A'opo-Asau area. The coastal 8 km transect extended from the coastal road to the ocean, whereas the 12.5 km montane transect started from the Sawmill and went up to Mauga Silisili (to 1725 m elevation) following an existing road that goes up to 1630 m.
2. Day and night time visual encounter surveys were conducted along the transects. Along these we count all reptiles observed and invasive mammals seen (e.g. pigs, cats, rats).
3. The last survey element was the use of sticky trap stations. These work well to capture all of the species of lizards, invasive ants, and rats (Fisher 2011).

From the sea to the coast road we placed transects about every 200 m along the road (stations 1-32). From the Sawmill to above the car park (one third of the way to camp) we placed them every 60 m (stations 33-168). The last two thirds of the way to camp, up to 1725 m, we placed traps every 20 m along the trail (stations 169-281). Thus we had 281 stations along the 20.5 km transect from sea level to 1725 m elevation (Figure 2.1.; Appendix 2.1). Each station consisted of three mouse sticky traps with one placed on the ground, one on a log, and the last one stapled to a tree at 1.5 m high (Figure 2.4). These traps were left overnight, and in some cases where there was rain all day, they were left for two nights so that the lizards experienced at least some portion of sun during the day. Additionally, two transects that went perpendicular to the road were run, one near the sawmill at 240 m elevation and one further up at 620 m elevation. These included three stations on each side of the road, at 40 m intervals. These were run to determine how far the YCA went into the interior forest habitats away from the road. Lizards were removed from the traps using vegetable oil and rubbing it along their body and them peeling them off the trap. YCA and Big-headed ants were counted on the traps. Live/dead rats, rat fur, and rat chew marks were recorded from the traps. Traps and flagging were removed at the end of the survey.

Figure 2.4. Timo installing a sticky trap on a tree (Photo by R.Fisher).

Figure 2.5. Removing trapped truck along track (Photo by R.Fisher).

Survey Schedule and sites visited

18-19 May – Uili and Fisher – Depart from Apia and San Diego, arrive Asau in evening.

20 May – Organize materials, purchase additional supplies and plan surveys.

21 May – Drive up A'opo trail, deal with vehicle issues (Figure 2.5), and walk to Base Camp. Conduct first night survey from Base Camp up slope towards Mauga Silisili.

22 May – Set sticky traps up trail towards Mauga Silisili (Figure 2.4). Conduct daytime survey along this transect. Set sticky traps from Base Camp half way down to car park. Conduct night survey up to Base Camp.

23 May – Conduct day survey downward half way to Car Park from Base Camp. Pick up sticky traps from Car Park to Base Camp transect (Figure 2.6). Then attempt to go up Mauga Silisili to meet rest of BIORAP team. Pick up sticky traps from Mauga Silisili trail to Base Camp. Fisher gets sick in evening.

24 May – Team airlifted by helicopter back to Asau. Fisher to health clinic. Rest of team sorting equipment, dealing with data from last three days.

25 May – Team set sticky traps from Sawmill to Car Park, then from Car Park to half way up to Base Camp. The team camped at the Car Park. Daytime visual encounter surveys were conducted between Sawmill and Car Park. The team also conducted night surveys half way up to Base Camp from Car Park.

26 May – Team waited for rain to slow/stop so that traps could be collected. Team picked up traps with captures between Car Park and Sawmill. Since only some had captures, and sun exposure was limited, these traps were replaced and all traps were left until 28 May for pick-up.

27 May – Team at Asau. Updated data, processed specimens, sorted gear, and re-provisioning (Figure 2.7).

28 May – Team collected sticky traps from Sawmill to Car Park, then from Car Park to half way to Base Camp. Team also conducted day time survey from Car Park to half way to Base Camp. A night survey was conducted also from Car Park back to Saw Mill.

29 May – Team set sticky traps from coast road to Volcanic Beach between A'opo and Asau (Figure 2.3). Team conducted night survey of this same transect (Figure 2.8).

30 May – Team collected sticky traps from coast road to Volcanic Beach between A'opo and Asau. Team conducted day time visual survey along this transect. Team finished processing and packing equipment.

31 May – Team returned to Apia with other BIORAP teams. Went to MNRE offices to meet about project. Spent night processing specimens, labelling specimens, and entering data.

1 June – Finished processing specimens, and sorting equipment.

2 June – Met with ACEO of MNRE regarding project and permits. Fisher departed for San Diego.

Figure 2.6. Reptile team at mountain end of mountain to coast transect.

Figure 2.7. Processing traps back at forestry office (Photo by R. Fisher).

Figure 2.8. Reptile team preparing for night surveys.

Figure 2.9. Success at recording the highest elevation record for a reptile in Oceania, a Samoan Skink (*Emoia samoensis*) at 1320 m ASL (Photo by R. Fisher).

5. OVERVIEW OF RESULTS

We did not detect any snakes during our surveys, although one was found by the Avifaunal team at their Site 1 (Camp by TV tower at end of forestry road from Asau). We detected lizards up to 1325 m elevation, although their density was very low (Figure 2.9). We found Yellow Crazy Ants (or any invasive ants on sticky traps) only below 560 m elevation (Figure 2.10; Figure 2.11). We did not find any ants on sticky traps above the car park, but did not take records on native ants on traps below the car park, to know exactly where they ended. We detected seven species of skinks and four species of geckos along the transects. The only three species of lizards we did not detect that are found in Samoa were the black skink (*Emoia nigra*), Indo-Pacific slender gecko (*Hemiphyllodactylus typus*), and the invasive house gecko (*Hemidactylus frenatus*).

Two most important findings were firstly that the higher elevations on Savai'i (above 560 m) are apparently free of invasive ants. This is very important as Hawai'i with a similar ecology has invasive ants greatly impacting its high elevation ecosystems. The other important finding is that Yellow Crazy ants are irrupting below 560 m on this side of Savai'i and, where they occurred, only a few species of lizards were able to persist with them. We consider them to apparently be creating a supercolony that spans from sea level to 500 m in elevation, with many traps swamped with these ants (Figure 2.10). Also few or no native ants were found on traps with the Crazy ants. Above 560 m there is a refugium for native lizards on Savai'i up to about 1325 m elevation. Additional results were that we made the first recordings for the Snake-eyed skink from Savai'i (Figure 2.11; Figure 2.12) including inland records to 240 m elevation. These are only the second records for the species from Samoa. We also found the Pacific stump-toed gecko (*Gehyra mutilata*) common along the lava fields near the coast (Figure 2.2; Figure 2.13). This gecko is relatively rare in Samoa so this was a surprise. Rats and cats were seen along the transects on the night surveys, and some rats were captured on the sticky traps (Figure 2.14). No pigs were observed. No Asian forest centipedes (Figure 2.15) were observed, although one was seen at the ferry dock on Upolu, and this species is very easy to detect during night surveys.

Figure 2.10. Trap full of Yellow Crazy Ants (Photo by R. Fisher).

Figure 2.11. Habitat for Snake-eyed Skink in Asau. First record for Savai'i caught on this coconut tree (Photo by R. Fisher).

Figure 2.12. Snake-eyed Skink (*Cryptoblepharus poecileopluris*) (Photo by C. Brown).

Figure 2.13. Pacific Stump-toed Gecko (*Gehyra mutilata*), this species was only found on the lava flow habitat (Photo by C. Brown).

Figure 2.14. Cat tracks in mud along trail to new mountain campsite (Photo by R. Fisher).

Figure 2.15. Asian Forest Centipede (*Scolopendra subspinipes*) (Photo by R. Fisher).

Figure 2.16. Samoan Skink (*Emoia samoensis*), this individual had many white spots which is not typical of this specie (Photo by C. Brown).

Figure 2.17. Polynesian Slender Skink (*Emoia tongana*) juvenile. This species lives on trees and was found in areas invaded by Yellow Crazy Ants (Photo by R. Fisher).

Species Results:

GECKOS

Pacific Stump-toed Gecko *Gehyra mutilata* (Figure 2.13)

This widespread Asian and Pacific species is not well known from Samoa or Savai'i. It was only found along the coastal lava flow at night and was very active on the lava. They were seen running across the lava even where no plants were growing and were the dominant gecko in this habitat and very common at night. They were not found very far inland or over 30 m elevation. Only one was captured on a sticky trap, although many were observed while conducting night surveys.

Oceania Gecko *Gehyra oceanica*

This is the largest gecko in Samoa and it is widespread across the islands. They were found between 80 m and 465 m in elevation and we captured 15 on sticky traps. Over 50% of the individuals were captured on traps on trees. They were detected at night as the most common species except on the low elevation lava flows.

Common House Gecko *Hemidactylus frenatus*

This is a recent invasive species into Samoa (Gill 1993, Case *et al*. 1994) and has been spreading around the urban areas of all islands. It is the only gecko in Samoa that vocalizes and it can be heard at night around structures and in rural areas. In Asau this gecko was the most abundant species on buildings. It was not detected along the elevational gradient as most of this was undeveloped and lacked structures. In the future it might spread into the disturbed forest and scrubland along the lava flows, as it seems to prefer more xeric habitats away from urban areas (Cole *et al*. 2005).

Indo-Pacific Slender Gecko *Hemiphyllodactylus typus*

This species was only recently recognized as being native to Samoa (Fisher *et al*. in review). It has been recorded only from three specimens from Upolu. The first is from 1895 and the second two from hatchlings hatched from eggs collected near Lake Lanoto'o in 1992 by George Zug and Ivan Ineich. Otherwise this species is unknown from the archipelago, and was unreported in Gill (1993) the last synthesis of the herpetofauna of Samoa. We did not detect this species on Savai'i.

Mourning Gecko *Lepidodactylus lugubris*

This is a widespread species across the Pacific region. It is known on Savai'i from just a couple of sites associated with urban habitats. One specimen was detected along the elevational gradient in the coastal lava field on a sticky trap. Two additional specimens were found at the Asau sawmill at night during night surveys. No individuals were found in the forest.

Pacific Slender-toed Gecko *Nactus pelagicus*

Gill (1993) reports this species from Savai'i for the first time, otherwise it is known from Upolu and the Aleipata Islands in Samoa. We caught 7 specimens on sticky traps along the elevational gradient. They were found between 314 m and 712 m in elevation. Their lack of occurrence at lower elevations may be the result of the YCA invasion, as they do occur at sea level at other sites in Samoa. They were almost evenly captured on tree, log, and ground traps.

SKINKS

Oceania Snake-eyed Skink *Cryptoblepharus poecilopleurus* (Figure 2.12)

This coastal skink was known only from Palolo Deep/Vaiala Beach and Mulinu'u on both coastal sides of Apia, on Upolu Island, and one specimen from Manono Island, within Samoa. Our survey detected it on Savai'i for the first time. We found it common in Asau, around the Va-I-Moana Hotel on rocks and coconut palms (Figure 2.11). We also caught eight specimens along our elevational gradient. Six of these individuals were captured on the lava field traps between 200 and 260 m inland and 20 m in elevation. These records are interesting as this species it typically only found right on the coast within the sea spray region. The last two records were exceptional as these two individuals were found about 8 kilometres inland along the transect at 240 m elevation. Finding these individuals so far inland and at such high elevation was very surprising. The rarity of this species probably reflects the impact of YCA along this transect.

Striped Small-scaled Skink *Emoia adspersa*

This skink is known from very few records in Samoa, and only two from Savai'i. We found it to be very rare, with only three records from the elevational gradient. Two individuals were from the coastal lava fields between Asau and A'opo, and the third specimen was at 688 m elevation, which was the highest elevation this species is known from. Also, it was over 12 kilometres inland. Typically this species is known from coastal habitats, including strand forest, mangrove forest, and is found in rural Apia in yards. One specimen collected by Zug and Ineich (USNM 322722) near Papapapaitai in 1992 is probably from around 600 m elevation. The two high elevation records for this species indicate that it possibly is or was more widespread throughout the inland forests of both Savai'i and Upolu. The absence of this species from the main YCA infested area of the transect suggests this species is sensitive to the presence of this invasive species.

White-bellied Copper-striped Skink *Emoia cyanura*

Historically this species was known from very few records from Savai'i Island, which was surprising as it was the species we captured the most along our transect, with 338 captures between the coast and 13.5 kilometres inland, and up to 917 m elevation from sea level. The species is known to prefer more disturbed habitats than the similar *Emoia impar*, and possibly this species, among all of the reptiles, can persist best with the Yellow Crazy ants. They typically occur on the ground or substrate (logs/rocks) near to the ground. At some point they seem to occur together at almost all parts of Samoa where they are found.

Dark-bellied Copper-striped Skink *Emoia impar*

Historically this species was known only from near Asau (Gill 1993) on Savai'i, although it is probably very widespread as it is on Upolu. Its rarity in collections appears due to its preference for more forested habitats that are less disturbed. It was the second most common lizard along the transect with 63 individuals captured between 4 and 14.5 km inland. Although a few individuals were observed nearer the coast none of these were captured. This species had the second highest elevation maximum as it occurred up to 990 m elevation. It appeared least common where there were the greatest numbers of Yellow Crazy ants.

South Pacific Black Skink *Emoia nigra*

This skink is very abundant in many places in Samoa. It was surprisingly absent from the elevational transect. This could be due to the combined impacts of Yellow Crazy ants and feral cats. It is apparently found still in Asau in the forest edge behind the forestry office (Finau Masoe pers. obs.) and was previously seen in Asau by Gill (Gill 1993). Typically in Samoa this species occurs on the forest floor and low on logs and trees.

Samoan Skink *Emoia samoensis*

This species is also poorly known from Savai'i. We captured 11 individuals along the elevational gradient. The species lives at sea level on Nu'utele Island and occurs widespread in Samoa, but we detected it only at elevations above where Yellow Crazy ants occurred. The first ones were captured at 770 m elevation and it occurred higher than any other species on Samoa, at 1320 m elevation. They occurred from 12.5 km inland to 16 km along the transect. Over 50% of our captures were made on the sticky traps on logs. This species showed the greatest Yellow Crazy ant response and appears to now be absent from the low elevation portions of Savai'i where the Yellow Crazy ants have invaded. A couple of the high elevation individuals had a lot of white spots, which is atypical for this species (Figure 2.16).

Polynesian Slender Treeskink *Emoia tongana*

This species is the most arboreal skink in Samoa with almost 75% of the 15 captures on the tree sticky traps (Figure 2.17). It was previously known from around Savai'i, but not inland. It occurred from 40 to 810 m in elevation, broadly overlapping with Yellow Crazy ant distribution. It only slightly overlapped its distribution with *Emoia samoensis*, which is a much larger species and may be a predator of it. It occurred over 12.5 km inland.

Moth Skink *Lipinia noctua*

This species is a widespread Pacific Island species occurring on many island groups. It is poorly known from Samoa but was the third most common lizard during our survey with 19 captures at sticky traps, and over 60% were on log traps. They occurred between 20 and 960 m elevation and up to 14 km inland along the transect.

BOA

Pacific Boa *Candoia bibroni*

No boas were detected along the elevational gradient. Only one boa was seen during this survey and that was by the avifauna team at their Camp 1 at the TV towers. This snake was at approximately 1000 m elevation and was sitting on a log in a marsh. The abundant evidence of cats along the elevational gradient is a concern as the cats are probably a very effective predator of this species and associated with its rarity.

Threats

- As mentioned above there is more chance YCA could adapt to lower temperatures on higher elevations, as recorded in Hawaii. When this happens the fauna and flora of Upland Savai'i will be at risk.
- The vehicle access road up to the campsite at Mata o le Afi is a pathway for invasive species to reach into the upland forests. In the next ten years Giant African Snails and YCA could become established in higher elevational ecosystems and become major threats to the pristine environments of uplands Savai'i.

RECOMMENDATIONS

- Propose biosecurity training to educate and support community understanding on risks of introduction and re-introduction of invasive species.
- Regulate the use of access roads that lead up to the pristine environment of the uplands of Savai'i.
- It is important to target local communities in conservation education programs, particularly those having ownership issues over their lands with significant biodiversity.
- Biosecurity is not well recognized by the community and should be one main focus for awareness and training opportunities in the future, especially to farmers and hunters.
- To provide training for local villages to help improve knowledge on conservation issues and to develop effective strategies to aid protection of key resources that are crucial to biodiversity but threatened in Samoa.
- Develop a strong relationship between relevant stakeholders to ensure successful implementation of all conservation actions in the future.
- Propose follow-up surveys to include areas that have not been surveyed in the past on Upland Savai'i to maximize data collection so we can plan possible conservation actions.
- Surveying village people on their traditional knowledge and experiences with their environment in the past could provide vital pieces of information for baseline data on how the diversity of the uplands Savai'i looked during the last millennium.

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Appendix 2.1 Reptile taxa found at survey stations

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
1	-13.498090	-172.588680	26	450	0	0	0	0	0	0	0	0	0	0	0	0	0
2	-13.499710	-172.587990	14	950	0	0	0	0	0	0	0	0	0	0	0	0	0
3	-13.501530	-172.587660	20	61	2	0	1	0	0	0	0	0	0	0	0	0	3
4	-13.503830	-172.587140	19	0	4	0	3	0	0	0	1	0	0	2	0	0	10
5	-13.506060	-172.586730	27	34	0	0	4	0	0	0	0	0	0	0	0	0	4
6	-13.508130	-172.586730	25	0	0	0	2	0	0	0	0	0	1	0	0	0	3
7	-13.509930	-172.586590	28	37	0	0	0	0	0	0	0	0	0	0	0	0	0
8	-13.512560	-172.586830	28	18	0	0	0	0	0	0	0	0	0	0	0	0	0
9	-13.515070	-172.586480	31	7	0	1	4	0	0	0	0	0	0	0	0	0	5
10	-13.517000	-172.585770	43	10	0	1	4	0	0	0	0	0	0	0	0	0	5
11	-13.519190	-172.586250	36	27	0	0	3	0	0	0	0	0	0	0	0	0	3
12	-13.519460	-172.588160	31	200	0	0	0	0	0	0	0	0	0	0	0	0	0
13	-13.521590	-172.587120	47	0	0	0	2	0	0	1	0	0	0	0	0	0	3
14	-13.523950	-172.586240	59	99	0	0	0	0	0	0	0	0	0	0	0	0	0
15	-13.526410	-172.585340	58	60	0	0	3	0	0	0	0	0	0	0	0	0	3
16	-13.528660	-172.584400	82	0	0	0	1	0	0	0	0	1	0	0	0	0	2
17	-13.531060	-172.584490	89	0	0	0	3	1	0	0	0	0	0	0	0	0	4
18	-13.530630	-172.587230	92	44	0	0	1	0	0	0	0	0	0	0	0	0	1
19	-13.530640	-172.589660	85	10	0	0	1	0	0	0	0	0	0	0	0	0	1
20	-13.530990	-172.592040	86	109	0	0	1	0	0	0	0	0	0	0	0	0	1
21	-13.531290	-172.594490	76	0	0	0	4	0	0	0	0	0	0	0	0	0	4
22	-13.532450	-172.596660	95	9	0	0	5	0	0	0	0	0	0	0	0	0	5
23	-13.533680	-172.593930	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	-13.534160	-172.592080	119	0	0	0	2	0	0	0	0	0	0	0	0	0	2
25	-13.534490	-172.590200	111	53	0	0	0	0	0	0	0	0	0	0	0	0	0
26	-13.535410	-172.588510	129	9	0	0	1	0	0	0	0	0	0	0	0	0	1
27	-13.536740	-172.587200	145	3	0	0	1	0	0	0	0	1	0	0	0	0	2
28	-13.537230	-172.585300	144	159	0	0	2	0	0	0	0	0	0	0	0	0	2
29	-13.537670	-172.583480	165	81	0	0	1	0	0	0	0	1	0	0	0	0	2
30	-13.538010	-172.581510	164	670	0	0	0	0	0	0	0	0	0	0	0	0	0
31	-13.538640	-172.579620	183	300	0	0	3	0	0	0	0	0	0	0	0	0	3
32	-13.538840	-172.577640	183	16	0	0	1	0	0	0	0	0	0	0	0	0	1
33	-13.538730	-172.548880	204	0	0	0	1	0	0	0	0	0	0	0	0	0	1
34	-13.539190	-172.548480	220	0	0	0	4	1	0	0	0	0	0	0	0	1	6
35	-13.539820	-172.548520	224	250	0	0	7	0	0	0	0	0	0	0	0	0	7
36	-13.540470	-172.548540	228	10	0	0	9	0	0	0	0	0	0	0	0	1	10

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
37	-13.541050	-172.548610	238	200	1	0	7	0	0	0	0	0	0	0	0	1	9
38	-13.541800	-172.548620	241	60	1	0	7	0	0	0	0	1	0	0	0	1	10
39	-13.542260	-172.548990	259	0	0	0	6	0	0	0	0	1	0	0	0	2	9
40	-13.542750	-172.549400	255	25	0	0	6	0	0	1	0	2	0	0	0	0	9
41	-13.543340	-172.549280	262	29	0	0	7	0	0	0	0	0	0	0	0	1	8
42	-13.543760	-172.549210	268	130	0	0	14	0	0	0	0	0	0	1	0	0	15
43	-13.544410	-172.549320	280	4	0	0	4	2	0	0	0	0	0	0	0	0	6
44	-13.544870	-172.549680	287	1	0	0	8	0	0	0	0	0	0	0	0	0	8
45	-13.545580	-172.549950	290	230	0	0	5	1	0	0	0	0	0	1	0	0	7
46	-13.546100	-172.549920	299	7	0	0	1	1	0	0	0	0	0	0	0	0	2
47	-13.546300	-172.549430	299	365	0	0	4	0	0	0	0	0	0	0	0	0	4
48	-13.546380	-172.548930	303	380	0	0	9	0	0	0	0	0	0	1	0	0	10
49	-13.546810	-172.548670	314	23	0	0	8	0	0	0	0	1	0	0	1	0	10
50	-13.547410	-172.548350	313	133	0	0	3	0	0	0	0	0	0	1	0	0	4
51	-13.547900	-172.548200	319	315	0	0	4	0	0	0	0	0	0	0	0	0	4
52	-13.548290	-172.548650	328	102	0	0	5	0	0	0	0	0	0	0	0	0	5
53	-13.548690	-172.548860	332	1	0	0	8	0	0	1	0	2	0	1	0	0	12
54	-13.549190	-172.548900	324	0	0	0	6	1	0	0	0	0	0	0	0	0	7
55	-13.549700	-172.548850	341	0	0	0	5	0	0	0	0	0	0	0	0	0	5
56	-13.550210	-172.548790	351	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	-13.550830	-172.548550	361	2	0	0	2	0	0	1	0	0	0	0	0	0	3
58	-13.551060	-172.548230	370	5	0	0	3	1	0	0	0	0	0	1	0	0	5
59	-13.551120	-172.547440	370	168	0	0	2	0	0	0	0	0	0	0	0	0	2
60	-13.551630	-172.547170	369	0	0	0	3	0	0	0	0	0	0	0	0	0	3
61	-13.551720	-172.546710	378	8	0	0	4	1	0	0	0	0	0	0	0	0	5
62	-13.551680	-172.546120	374	30	0	0	10	0	0	1	0	1	0	0	0	0	12
63	-13.552320	-172.546030	380	0	0	0	4	1	0	1	0	0	0	0	1	0	7
64	-13.552830	-172.546040	393	0	0	0	7	2	0	0	0	1	0	0	0	0	10
65	-13.553340	-172.545970	413	1	0	0	4	3	0	1	0	0	0	0	0	0	8
66	-13.553530	-172.545540	413	26	0	0	9	0	0	0	0	0	0	0	0	1	10
67	-13.553610	-172.545090	420	93	0	0	8	0	0	0	0	0	0	0	0	0	8
68	-13.554150	-172.544980	449	50	0	0	6	0	0	1	0	1	0	0	0	0	8
69	-13.554450	-172.544510	444	14	0	0	7	0	0	0	0	0	0	0	0	0	7
70	-13.554830	-172.544430	448	7	0	0	5	1	0	1	0	0	0	0	0	0	7
71	-13.555150	-172.544700	451	2	0	0	3	0	0	1	0	1	0	0	0	0	5
72	-13.555700	-172.544700	463	13	0	0	11	0	0	1	0	0	0	0	0	0	12

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
73	-13.556000	-172.544240	465	25	0	0	4	0	0	1	0	1	0	0	0	0	6
74	-13.556300	-172.543940	473	17	0	0	3	0	0	1	0	0	0	0	1	0	5
75	-13.556510	-172.543430	483	17	0	0	0	0	0	0	0	0	0	0	0	0	0
76	-13.556840	-172.543100	496	60	0	0	0	0	0	0	0	0	0	0	0	0	0
77	-13.557140	-172.542750	495	20	0	0	1	0	0	0	0	0	0	0	1	0	2
78	-13.557470	-172.542440	498	153	0	0	0	2	0	0	0	0	0	0	0	0	2
79	-13.557950	-172.541910	507	38	0	0	2	0	0	0	0	0	0	0	0	0	2
80	-13.558340	-172.541520	519	345	0	0	1	0	0	0	0	0	0	0	0	0	1
81	-13.558760	-172.541090	517	70	0	0	6	1	0	0	0	0	0	1	1	0	9
82	-13.559300	-172.540640	500	0	0	0	0	0	0	0	0	0	0	1	0	0	1
83	-13.559610	-172.540260	514	0	0	0	3	0	0	0	0	0	0	0	0	0	3
84	-13.559770	-172.539870	528	0	0	0	2	2	0	0	0	0	0	1	0	0	5
85	-13.560340	-172.539880	564	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	-13.561000	-172.539870	576	0	0	0	6	1	0	0	0	0	0	2	0	0	9
87	-13.561530	-172.540210	597	0	0	0	0	1	0	0	0	0	0	0	0	0	1
88	-13.562160	-172.540340	586	0	0	0	3	0	0	0	0	0	0	0	0	0	3
89	-13.562570	-172.540140	597	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	-13.563250	-172.540120	616	0	0	0	1	0	0	0	0	0	0	0	0	0	1
91	-13.564380	-172.539360	640	0	0	0	2	2	0	0	0	0	0	0	0	0	4
92	-13.565060	-172.539130	638	0	0	0	6	1	0	1	0	0	0	0	0	0	8
93	-13.565880	-172.538700	664	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	-13.566640	-172.538610	690	0	0	0	1	3	0	0	0	0	0	0	1	0	5
95	-13.566950	-172.538980	688	0	0	1	1	2	0	0	0	0	0	0	0	0	4
96	-13.567860	-172.539060	703	0	0	0	1	3	0	0	0	0	0	1	0	0	5
97	-13.568420	-172.538890	712	0	0	0	1	1	0	0	0	0	0	1	1	0	4
98	-13.568980	-172.538640	728	0	0	0	0	1	0	0	0	0	0	0	0	0	1
99	-13.569570	-172.538580	739	0	0	0	0	2	0	0	0	0	0	0	0	0	2
100	-13.570160	-172.538420	773	0	0	0	2	2	1	0	0	0	0	0	0	0	5
101	-13.570590	-172.538280	773	0	0	0	1	2	1	0	0	0	0	0	0	0	4
102	-13.571300	-172.538480	777	0	0	0	0	1	0	0	0	0	0	0	0	0	1
103	-13.571810	-172.538260	794	0	0	0	2	0	0	0	0	0	0	0	0	0	2
104	-13.572490	-172.538570	810	0	0	0	1	2	1	1	0	0	0	0	0	0	5
105	-13.573030	-172.538380	805	0	0	0	0	2	1	0	0	0	0	0	0	0	3
106	-13.573500	-172.538200	820	0	0	0	1	1	0	0	0	0	0	0	0	0	2
107	-13.574290	-172.537980	832	0	0	0	1	4	0	0	0	0	0	0	0	0	5
108	-13.574730	-172.537910	834	0	0	0	1	1	0	0	0	0	0	0	0	0	2
109	-13.575290	-172.537730	838	0	0	0	0	1	0	0	0	0	0	0	0	0	1
110	-13.575960	-172.537660	848	0	0	0	1	0	0	0	0	0	0	0	0	0	1

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
111	-13.576500	-172.537480	861	0	0	0	0	0	0	0	0	0	0	0	0	0	0
112	-13.577230	-172.537520	874	0	0	0	1	0	1	0	0	0	0	1	0	0	3
113	-13.577710	-172.537630	890	0	0	0	0	1	0	0	0	0	0	1	0	0	2
114	-13.578240	-172.537730	900	0	0	0	1	0	1	0	0	0	0	0	0	0	2
115	-13.578720	-172.537880	905	0	0	0	1	1	0	0	0	0	0	1	0	0	3
116	-13.579030	-172.537600	917	0	0	0	2	0	0	0	0	0	0	0	0	0	2
117	-13.579440	-172.537410	921	0	0	0	0	0	1	0	0	0	0	0	0	0	1
118	-13.579890	-172.537190	925	0	0	0	0	0	1	0	0	0	0	0	0	0	1
119	-13.580490	-172.536970	929	0	0	0	0	1	0	0	0	0	0	0	0	0	1
120	-13.581180	-172.536880	936	0	0	0	0	1	0	0	0	0	0	0	0	0	1
121	-13.581610	-172.536710	940	0	0	0	0	0	0	0	0	0	0	0	0	0	0
122	-13.582320	-172.536640	945	0	0	0	0	2	0	0	0	0	0	0	0	0	2
123	-13.583050	-172.536720	951	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124	-13.583180	-172.536300	950	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	-13.583430	-172.535780	950	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126	-13.584040	-172.535310	963	0	0	0	0	0	0	0	0	0	0	1	0	0	1
127	-13.584410	-172.535000	967	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	-13.584910	-172.534820	972	0	0	0	0	0	1	0	0	0	0	0	0	0	1
129	-13.585300	-172.534470	973	0	0		0	1	1	0	0	0	0	0	0	0	2
130	-13.585940	-172.534320	980	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131	-13.586480	-172.533790	990	0	0	0	0	2	0	0	0	0	0	0	0	0	2
132	-13.586820	-172.533220	1010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	-13.587120	-172.533350	1016	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	-13.587250	-172.532870	1025	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	-13.587670	-172.532620	1042	0	0	0	0	0	0	0	0	0	0	0	0	0	0
136	-13.587900	-172.532430	1042	0	0	0	0	0	0	0	0	0	0	0	0	0	0
137	-13.588410	-172.532350	1056	0	0	0	0	0	0	0	0	0	0	0	0	0	0
138	-13.588780	-172.532380	1068	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	-13.589110	-172.532300	1079	0	0	0	0	0	0	0	0	0	0	0	0	0	0
140	-13.589470	-172.532330	1086	0	0	0	0	0	0	0	0	0	0	0	0	0	0
141	-13.589810	-172.531960	1096	0	0	0	0	0	0	0	0	0	0	0	0	0	0
142	-13.590090	-172.531830	1103	0	0	0	0	0	0	0	0	0	0	0	0	0	0
143	-13.590480	-172.531790	1124	0	0	0	0	0	0	0	0	0	0	0	0	0	0
144	-13.590970	-172.532080	1130	0	0	0	0	0	0	0	0	0	0	0	0	0	0
145	-13.591180	-172.531620	1145	0	0	0	0	0	0	0	0	0	0	0	0	0	0
146	-13.591710	-172.531830	1165	0	0	0	0	0	0	0	0	0	0	0	0	0	0
147	-13.591720	-172.531440	1170	0	0	0	0	0	0	0	0	0	0	0	0	0	0
148	-13.592000	-172.531890	1181	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
149	-13.592220	-172.531430	1206	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	-13.592940	-172.531900	1233	0	0	0	0	0	0	0	0	0	0	0	0	0	0
151	-13.593180	-172.531470	1241	0	0	0	0	0	0	0	0	0	0	0	0	0	0
152	-13.593510	-172.531040	1260	0	0	0	0	0	0	0	0	0	0	0	0	0	0
153	-13.593580	-172.530520		0	0	0	0	0	0	0	0	0	0	0	0	0	0
154	-13.593780	-172.530100	1274	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	-13.594310	-172.529640	1282	0	0	0	0	0	0	0	0	0	0	0	0	0	0
156	-13.594900	-172.529350	1291	0	0	0	0	0	0	0	0	0	0	0	0	0	0
157	-13.595280	-172.529040	1295	0	0	0	0	0	0	0	0	0	0	0	0	0	0
158	-13.595830	-172.528820	1305	0	0	0	0	0	0	0	0	0	0	0	0	0	0
159	-13.596090	-172.528410	1314	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160	-13.596440	-172.528070	1321	0	0	0	0	0	1	0	0	0	0	0	0	0	1
161	-13.596790	-172.527810	1329	0	0	0	0	0	0	0	0	0	0	0	0	0	0
162	-13.597160	-172.527300	1344	0	0	0	0	0	0	0	0	0	0	0	0	0	0
163	-13.597260	-172.526880	1347	0	0	0	0	0	0	0	0	0	0	0	0	0	0
164	-13.597450	-172.526420	1355	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	-13.597670	-172.526010	1360	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166	-13.597980	-172.525650	1366	0	0	0	0	0	0	0	0	0	0	0	0	0	0
167	-13.598250	-172.525200	1371	0	0	0	0	0	0	0	0	0	0	0	0	0	0
168	-13.598500	-172.524740	1383	0	0	0	0	0	0	0	0	0	0	0	0	0	0
169	-13.598520	-172.524660	1383	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	-13.598480	-172.524300	1387	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	-13.598320	-172.524040	1382	0	0	0	0	0	0	0	0	0	0	0	0	0	0
172	-13.598230	-172.523660	1387	0	0	0	0	0	0	0	0	0	0	0	0	0	0
173	-13.598430	-172.522880	1395	0	0	0	0	0	0	0	0	0	0	0	0	0	0
174	-13.598880	-172.522560	1408	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	-13.599650	-172.522370	1430	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	-13.600040	-172.522260	1443	0	0	0	0	0	0	0	0	0	0	0	0	0	0
177	-13.600490	-172.522170	1456	0	0	0	0	0	0	0	0	0	0	0	0	0	0
178	-13.601060	-172.521930	1465	0	0	0	0	0	0	0	0	0	0	0	0	0	0
179	-13.601600	-172.521290	1475	0	0	0	0	0	0	0	0	0	0	0	0	0	0
180	-13.601930	-172.521010	1482	0	0	0	0	0	0	0	0	0	0	0	0	0	0
181	-13.602310	-172.520860	1488	0	0	0	0	0	0	0	0	0	0	0	0	0	0
182	-13.602730	-172.520710	1497	0	0	0	0	0	0	0	0	0	0	0	0	0	0
183	-13.603130	-172.520360	1504	0	0	0	0	0	0	0	0	0	0	0	0	0	0
184	-13.603370	-172.520150	1507	0	0	0	0	0	0	0	0	0	0	0	0	0	0
185	-13.603820	-172.519720	1524	0	0	0	0	0	0	0	0	0	0	0	0	0	0
186	-13.603980	-172.519370	1527	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
187	-13.604410	-172.518950	1538	0	0	0	0	0	0	0	0	0	0	0	0	0	0
188	-13.604780	-172.518700	1542	0	0	0	0	0	0	0	0	0	0	0	0	0	0
189	-13.605190	-172.518490	1548	0	0	0	0	0	0	0	0	0	0	0	0	0	0
190	-13.605690	-172.518210	1552	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	-13.606200	-172.517870	1566	0	0	0	0	0	0	0	0	0	0	0	0	0	0
192	-13.606600	-172.517620	1579	0	0	0	0	0	0	0	0	0	0	0	0	0	0
193	-13.606830	-172.517080	1592	0	0	0	0	0	0	0	0	0	0	0	0	0	0
194	-13.606900	-172.516650	1595	0	0	0	0	0	0	0	0	0	0	0	0	0	0
195	-13.607000	-172.516280	1595	0	0	0	0	0	0	0	0	0	0	0	0	0	0
196	-13.607090	-172.515880	1596	0	0	0	0	0	0	0	0	0	0	0	0	0	0
197	-13.607240	-172.515530	1603	0	0	0	0	0	0	0	0	0	0	0	0	0	0
198	-13.607450	-172.515220	1616	0	0	0	0	0	0	0	0	0	0	0	0	0	0
199	-13.607530	-172.514870	1610	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200	-13.607840	-172.514560	1611	0	0	0	0	0	0	0	0	0	0	0	0	0	0
201	-13.608230	-172.514530	1602	0	0	0	0	0	0	0	0	0	0	0	0	0	0
202	-13.608580	-172.514340	1602	0	0	0	0	0	0	0	0	0	0	0	0	0	0
203	-13.608890	-172.513990	1615	0	0	0	0	0	0	0	0	0	0	0	0	0	0
204	-13.608940	-172.513600	1617	0	0	0	0	0	0	0	0	0	0	0	0	0	0
205	-13.609060	-172.513360	1627	0	0	0	0	0	0	0	0	0	0	0	0	0	0
206	-13.609200	-172.512940	1640	0	0	0	0	0	0	0	0	0	0	0	0	0	0
207	-13.609270	-172.512890	1647	0	0	0	0	0	0	0	0	0	0	0	0	0	0
208	-13.609490	-172.512610	1654	0	0	0	0	0	0	0	0	0	0	0	0	0	0
209	-13.609540	-172.512260	1648	0	0	0	0	0	0	0	0	0	0	0	0	0	0
210	-13.609300	-172.512060	1635	0	0	0	0	0	0	0	0	0	0	0	0	0	0
211	-13.609200	-172.511750	1630	0	0	0	0	0	0	0	0	0	0	0	0	0	0
212	-13.609220	-172.511460	1625	0	0	0	0	0	0	0	0	0	0	0	0	0	0
213	-13.609340	-172.511110	1624	0	0	0	0	0	0	0	0	0	0	0	0	0	0
214	-13.609590	-172.510960	1632	0	0	0	0	0	0	0	0	0	0	0	0	0	0
215	-13.609910	-172.510860	1639	0	0	0	0	0	0	0	0	0	0	0	0	0	0
216	-13.610160	-172.510830	1645	0	0	0	0	0	0	0	0	0	0	0	0	0	0
217	-13.610470	-172.510840	1644	0	0	0	0	0	0	0	0	0	0	0	0	0	0
218	-13.610560	-172.510620	1647	0	0	0	0	0	0	0	0	0	0	0	0	0	0
219	-13.610560	-172.508500	1651	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220	-13.610480	-172.508020	1637	0	0	0	0	0	0	0	0	0	0	0	0	0	0
221	-13.610320	-172.507650	1643	0	0	0	0	0	0	0	0	0	0	0	0	0	0
222	-13.610260	-172.507400	1635	0	0	0	0	0	0	0	0	0	0	0	0	0	0
223	-13.610150	-172.507060	1626	0	0	0	0	0	0	0	0	0	0	0	0	0	0
224	-13.610280	-172.506660	1626	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
225	-13.610650	-172.506090	1635	0	0	0	0	0	0	0	0	0	0	0	0	0	0
226	-13.610770	-172.505810	1657	0	0	0	0	0	0	0	0	0	0	0	0	0	0
227	-13.610810	-172.505580	1652	0	0	0	0	0	0	0	0	0	0	0	0	0	0
228	-13.610680	-172.505400	1644	0	0	0	0	0	0	0	0	0	0	0	0	0	0
229	-13.610690	-172.505200	1644	0	0	0	0	0	0	0	0	0	0	0	0	0	0
230	-13.610620	-172.504930	1639	0	0	0	0	0	0	0	0	0	0	0	0	0	0
231	-13.610670	-172.504720	1639	0	0	0	0	0	0	0	0	0	0	0	0	0	0
232	-13.610690	-172.504510	1641	0	0	0	0	0	0	0	0	0	0	0	0	0	0
233	-13.610450	-172.504390	1641	0	0	0	0	0	0	0	0	0	0	0	0	0	0
234	-13.610330	-172.504280	1645	0	0	0	0	0	0	0	0	0	0	0	0	0	0
235	-13.610120	-172.504070	1652	0	0	0	0	0	0	0	0	0	0	0	0	0	0
236	-13.610060	-172.503940	1654	0	0	0	0	0	0	0	0	0	0	0	0	0	0
237	-13.609930	-172.503830	1654	0	0	0	0	0	0	0	0	0	0	0	0	0	0
238	-13.609920	-172.503650	1663	0	0	0	0	0	0	0	0	0	0	0	0	0	0
239	-13.609850	-172.503470	1648	0	0	0	0	0	0	0	0	0	0	0	0	0	0
240	-13.609930	-172.503290	1658	0	0	0	0	0	0	0	0	0	0	0	0	0	0
241	-13.610010	-172.503190	1650	0	0	0	0	0	0	0	0	0	0	0	0	0	0
242	-13.610040	-172.502960	1650	0	0	0	0	0	0	0	0	0	0	0	0	0	0
243	-13.610220	-172.502780	1654	0	0	0	0	0	0	0	0	0	0	0	0	0	0
244	-13.610360	-172.502680	1654	0	0	0	0	0	0	0	0	0	0	0	0	0	0
245	-13.610600	-172.502600	1657	0	0	0	0	0	0	0	0	0	0	0	0	0	0
246	-13.610660	-172.502450	1657	0	0	0	0	0	0	0	0	0	0	0	0	0	0
247	-13.610840	-172.502390	1658	0	0	0	0	0	0	0	0	0	0	0	0	0	0
248	-13.611000	-172.502390	1660	0	0	0	0	0	0	0	0	0	0	0	0	0	0
249	-13.611070	-172.502250	1660	0	0	0	0	0	0	0	0	0	0	0	0	0	0
250	-13.611330	-172.502150	1666	0	0	0	0	0	0	0	0	0	0	0	0	0	0
251	-13.611490	-172.501980	1665	0	0	0	0	0	0	0	0	0	0	0	0	0	0
252	-13.611650	-172.501880	1668	0	0	0	0	0	0	0	0	0	0	0	0	0	0
253	-13.611800	-172.501800	1669	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Station #	Latitude	Longitude	Elev (m)	YCA	CRPE	EMAD	EMCY	EMIM	EMSA	EMTO	GEMU	GEOC	LELU	LINO	NAPE	UNLI	Total Liz.
254	-13.611900	-172.501650	1672	0	0	0	0	0	0	0	0	0	0	0	0	0	0
255	-13.612060	-172.501500	1674	0	0	0	0	0	0	0	0	0	0	0	0	0	0
256	-13.612210	-172.501460	1679	0	0	0	0	0	0	0	0	0	0	0	0	0	0
257	-13.612370	-172.501340	1683	0	0	0	0	0	0	0	0	0	0	0	0	0	0
258	-13.612520	-172.501210	1684	0	0	0	0	0	0	0	0	0	0	0	0	0	0
259	-13.612660	-172.501030	1683	0	0	0	0	0	0	0	0	0	0	0	0	0	0
260	-13.612880	-172.500980	1683	0	0	0	0	0	0	0	0	0	0	0	0	0	0
261	-13.613040	-172.500810	1687	0	0	0	0	0	0	0	0	0	0	0	0	0	0
262	-13.613200	-172.500760	1692	0	0	0	0	0	0	0	0	0	0	0	0	0	0
263	-13.613400	-172.500670	1688	0	0	0	0	0	0	0	0	0	0	0	0	0	0
264	-13.613580	-172.500650	1693	0	0	0	0	0	0	0	0	0	0	0	0	0	0
265	-13.613750	-172.500530	1693	0	0	0	0	0	0	0	0	0	0	0	0	0	0
266	-13.613930	-172.500440	1692	0	0	0	0	0	0	0	0	0	0	0	0	0	0
267	-13.614050	-172.500270	1690	0	0	0	0	0	0	0	0	0	0	0	0	0	0
268	-13.614160	-172.500130	1696	0	0	0	0	0	0	0	0	0	0	0	0	0	0
269	-13.614330	-172.499960	1699	0	0	0	0	0	0	0	0	0	0	0	0	0	0
270	-13.614430	-172.499760	1704	0	0	0	0	0	0	0	0	0	0	0	0	0	0
271	-13.614490	-172.499420	1707	0	0	0	0	0	0	0	0	0	0	0	0	0	0
272	-13.614530	-172.499310	1707	0	0	0	0	0	0	0	0	0	0	0	0	0	0
273	-13.614500	-172.499110	1710	0	0	0	0	0	0	0	0	0	0	0	0	0	0
274	-13.614650	-172.498960	1712	0	0	0	0	0	0	0	0	0	0	0	0	0	0
275	-13.614810	-172.498770	1712	0	0	0	0	0	0	0	0	0	0	0	0	0	0
276	-13.614990	-172.498660	1713	0	0	0	0	0	0	0	0	0	0	0	0	0	0
277	-13.615020	-172.498430	1713	0	0	0	0	0	0	0	0	0	0	0	0	0	0
278	-13.615160	-172.498310	1713	0	0	0	0	0	0	0	0	0	0	0	0	0	0
279	-13.615310	-172.498210	1713	0	0	0	0	0	0	0	0	0	0	0	0	0	0
280	-13.615740	-172.497900	1710	0	0	0	0	0	0	0	0	0	0	0	0	0	0
281	-13.616200	-172.497210	1723	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total:					**8**	**3**	**338**	**63**	**11**	**15**	**1**	**15**	**1**	**19**	**7**	**8**	**489**

KEY: YCA – Yellow Crazy Ants; CRPE – Cryptobleparus; EMAD – Emoia adspersa; EMCY – Emoia cyanura; EMIM – Emoia impar; EMSA – Emoia samoensis;

EMTO – Emoia tongana; GEMU – Gehyra mutilata; GEOC – Gehyra oceanica; LELU – Lepidodacylus lugubris; LINO – Lipinia noctua; NAPE – Nactus pelagicus.

CHAPTER 3
Report on the birds of Upland Savai'i

DAVID BUTLER

Team Members: Mark O'Brien (Birdlife), Kirsty Swinnerton (Island Conservation), Rebecca Stirnemann, Vilikesa Masibalavu (Conservation International), Becky Harris, Fialelei Enoka (MNRE), Moemalo Peninsula Leala (MNRE).

1. SUMMARY

The Avifauna team visited three main areas during the BIORAP in May 2012. The first was the forests above Asau towards Mauga Maugaloa; the second was the forests above A'opo on the trail to Mauga Mata o Le Afi and beyond to Mauga Silisili; and the third was around several craters nearer the centre of the island. The first two included areas where there were possible sightings of the Puna'e or Samoan Moorhen last century and the third, accessible only by helicopter, is unlikely to have ever before been visited by scientists.

No trace of the Puna'e was found. Though there are still significant areas in which searches for this bird have not been undertaken, the survey tends to confirm the view that it is extinct (last confirmed report 1873).

Only a single uncorroborated sighting of the endangered Manumea or Tooth-billed pigeon was made, despite the presence of large numbers of its food trees, raising concern that its situation may now be critical. Reasonable numbers were recorded in a previous upland survey in 1996 but the area no longer seems to be a stronghold for this species. In addition no Tuaimeo or Shy Ground-doves were seen.

Small number of the endangered Ma'oma'o or Mao were found at the second and third sites, re-enforcing a picture that it has particular habitat requirements which are now hard to find.

Other forest birds were found in good numbers including the Matapaepae or Samoan White-eye which is found only in the Savai'i uplands. It was sufficiently numerous for the team to recommend a change in its current IUCN status.

One seabird, a Tahiti Petrel, was found at an inland crater, a first record for this species in Samoa. This suggests that the uplands may still be an important area for nesting seabirds and further surveys are needed during the breeding season.

The survey suggested that the uplands contain some of the same threats that have caused Samoa's rarest birds to largely disappear from the lowlands. Even the craters right in the interior were infested with some weeds and rats, wild cats and feral pigs and cattle were encountered in different areas. Hunting was obviously occurring at the more accessible sites. Clear-felling over the past few years of the lowland forests of A'opo-Letui-Sasina, identified in 1992 as one of 5 key sites for biodiversity conservation in Samoa, will also have had devastating consequences for the rarer biodiversity in that part of Savai'i.

The uplands still represent a large area of forest very significant for the conservation of the country's biodiversity. The team would encourage all communities to consider their upland areas as a treasure that they will care for on behalf of future generations, not an area to be exploited for logging or the hunting of birds and bats. Without this care, Samoa is likely to lose more of the unique species that are important to the country's culture and identity.

2. INTRODUCTION

Avifauna was one of the key elements of the BIORAP as identified in the following section from the Grant Agreement between SPREP and CEPF.

SPECIFIC FOCUS OF THE PROJECT

The upland ecosystems of Savai'i hold the key to the possible survival of the Samoan Moorhen (or Woodhen) (Puna'e) which has not been recorded since 1873 (refer Figure 3.1). *These habitats could also confirm the conservation status of the tooth-billed pigeon (Manumea) that has recently become of concern to ornithologists. The study area is also a likely stronghold for several other rare species and is the only site where the endemic Samoan White-eye has been recorded.*

It is proposed that this project will carry out surveys in the uplands, both in areas where possible sightings of the puna'e have been made in the west above A'opo and Asau and also in eastern areas that have not previously been surveyed by ecologists.

The main objective of the avifauna survey was '*to confirm the status of several key species, in particular Puna'e, Manumea, and Samoan White-eye'*. It was recognised at the outset that this was a significant challenge as the Savai'i uplands is a very large area with very limited access. Initial planning in March identified 8 areas for survey which between them would give the level of coverage needed to achieve this objective. Two experienced avifauna teams were put together and the survey started a week before other elements of the BIORAP and finished a day later to maximise coverage. In the event, as a result of timeframes, logistics and bad weather, only four of the eight areas were visited so the survey's conclusions need to be considered in this context.

Figure 3.1. Early engraving of the Puna'e

3. METHODS AND SITE DESCRIPTION

3.1 Survey Teams

Two teams were established each with three ornithologists supported by staff of the Ministry of Natural Resources & Environment (MNRE) and villagers from A'opo Village:

Team A – Ornithologists

- David Butler (team leader, self-employed, Manager of CEPF-funded project on tooth-billed pigeon and mao conservation and worked periodically in Samoa since 1993)
- Kirsty Swinnerton (Program Manager, Island Conservation, Puerto Rico),
- Vilikesa Masibalavu (Conservation International, Fiji and formerly of Birdlife International Pacific)

Team B – Ornithologists

- Mark O'Brien (team leader, Senior Technical Advisor, BirdLife International Pacific Programme, Fiji)
- Rebecca Stirnemann (Massey University, NZ Student studying the Mao in Samoa since July 2010 for a PhD)
- Becky Harris (Volunteer undertaking her second stint in support of R. Stirnemann's study)

MNRE personnel

- Fialelei Enoka, Parks & Reserves. Support of both teams (week1) and team B from 22nd to 26th May.
- Moemalo Peninsula Leala, Forestry Division. Team A from 22nd to 30 May
- Tupai Tanielu Tipa, Forestry Division. Support of both teams (week 1)

The teams were also supported on two occasions by villagers from A'opo.

3.2 Methodology

The survey was based on experienced teams observing birds, noting their calls, and searching for burrows and footprints in mud, supplemented by automatic sound recorders that could be positioned to continuously record bird calls over a fixed time frame.

Teams drove, drove and walked, or were airlifted by helicopters into sites where they established base camps. Observations were typically made from these camps at dawn (starting c.6am just before the first birds started calling) and teams then walked out for the day, often cutting routes through the forest, set out recorders and returned to camp for further surveys at dusk. Typically a team cut a trail in the morning placing an observer directly behind those cutting the route with bush-knives to detect any birds that they flushed, then walked slowly back spread out along that trail later, stopping at intervals to observe and listen for birds. Team members each made a series of 30-minute point counts to provide some quantitative information, recording which species were heard or seen every 5 minutes within the 30. In addition they estimated the number of individuals of certain native species present over the whole period: pigeons and doves, Blue-crowned Lory, Island Thrush, Samoan White-eye, Mao and seabirds; and introduced birds (Jungle and Indian Mynas and Red-vented Bulbuls). These counts were undertaken opportunistically, with a good selection of sites being located on ridges, crater walls or other sites that offered good views over areas of forest.

Ground searches were also carried out in several wetlands and swampy areas, looking for feathers, footprints or nests and seeking to flush out any rails or crakes present.

The automatic sound recorders (Figure 3.2) were built and developed by the New Zealand Department of Conservation. The recorders were set to 'high' – the recommended setting for forest birds. They were typically placed to record over two time periods, 5am to 9am and 5pm to 9pm, covering the periods of peak calling around dawn and dusk. However a few were set to record throughout the night in craters and one was used, 'hand-held', to record the calls of a seabird.

The recordings obtained have not been analysed at the time of this preliminary report except to identify a seabird. We will use computer software (including Xbat with Matlab) to detect different calls to determine the presence of priority species at each location. Priority species include the Ma'oma'o and Manumea. We anticipate that, with Ma'oma'o at least, we will be able to automatically record the frequency of calls at each of the sites for a range of time periods. We would also hope to be able to use the 'chick call' of Ma'oma'o as a coarse measure of productivity across the Savai'i uplands. We will also need to check the recordings for any calls that are not recognisable and that might possibly be Puna'e. This will take some considerable time, however. Finally we hope that we will be able to identify calls that accord with current understanding of Manumea, and follow these up to confirm whether they are Manumea or other species of pigeon.

Limited rat trapping was carried out at 2 sites at 975-1000m and 2 sites at 1,600m and observations made of mammals and their sign including native flying-foxes. When the scats of cats were found they were examined to determine what the individuals had been feeding on.

Figure 3.2. Moemalo setting up an automatic recorder (Photo by D. Butler).

3.3 Survey schedule and sites visited

13 May – Butler and Swinnerton – field visit for familiarisation with bird calls, Upolu

14-15 May – Planning and purchase of supplies & equipment

15 May – O'Brien and Masibalavu arrive in evening – all team members now in Samoa

16 May – Apia to Asau (via 8am ferry); teams A & B drive to site 1 camp by TV tower

17-19 May – Work from site 1 including searches of craters north of Mauga Elietoga

20 May – Butler on helicopter reconnaissance of the island; loading of equipment & food for one helicopter supply trip to Base Camp

21 May – Teams A & B drive up A'opo trail and walk to Base Camp

22 May – Teams airlifted by helicopter, A to site 2 and B to site 3 (together with entomologist team)

23-26 May –Teams at sites 2 and 3 – two days longer than planned due to bad weather

27 May – Teams at Asau – drying gear, downloading recorder data and re-provisioning

28 May – Teams drove to road end of A'opo trail. Team A camped there, team B walked up to Base Camp

29 May – Team A surveying from A'opo road end. Team B surveyed from base camp including airlift into nearby crater by helicopter.

30 May – Team B walked to road end. Teams drove to Asau setting recorders out in trail on the way.

31 May – Stirnemann and Harris returned to Apia with other BIORAP teams. Butler, O'Brien, Swinnerton and Masibalavu surveyed A'opo lowland forest for pigeons.

1 June – Butler, O'Brien, Swinnerton and Masibalavu returned to Apia (2pm ferry) after morning survey for pigeons on Patamea inland road.

Figure 3.3 shows sites visited by the bird survey team.

Figure 3.3. Sites surveyed by avifauna teams

SITE 1 (FIGURE 3.4 AND 3.5)

Camp by TV tower at end of forestry road from Asau at 920m above Eucalyptus plantation. Surveyed to craters at waypoints 245 and 252. Teams A & B.

SITE 2 (FIGURES 3.6-3.8)

Camp within crater '1347' by diverse wetland. Surveyed into adjacent crater at waypoint 265 and down a stream into valley floor at 271 to the north. Team A.

SITE 3

Camp within unnumbered crater (S13.6440 W172.413). Surveyed around rim of crater, recording both within the crater and outwards over the surrounding upland area. Team B and invertebrate team.

MAIN CAMP (FIGURE 3.9)

Both teams carried out morning observations on 22 May. Team B based there 28-30 May and surveyed down lava field on 28th, and were helicoptered into a marsh at S13.62126 W172.48615 on the 29th from where they walked to base camp, taking a detour up Mauga Silisili en route.

A'OPO ROAD END (FIGURE 3.10)

Team A based there 29-30 May and surveyed up trail to Main Camp and down trail to 800m asl. and alongside streams on either side of road end.

A'OPO LOWLAND FOREST (FIGURE 3.11)

Some of combined team visited area north of A'opo village to S13.52439 W172.52789 at 119m asl on 31 May with 2 local guides and surveyed for pigeons on Asau-Letui road and side roads.

PATAMEA INLAND ROAD

Combined team spent 1–2 hours driving slowly along road on morning of 1 June from Samalae'ulu to north of Salelologa and stopping at intervals to search for pigeons.

Figure 3.4. In overgrown *Eucalyptus* plantation at site 1 (Photo by D. Butler).

Figure 3.5. South from the TV tower ridge at site 1 (paler canopy are *Eucalyptus)* (Photo by D. Butler).

Figure 3.6. Helicopter in site 2 ('1347' crater) (Photo by K. Swinnerton).

Figure 3.7. Site 2 largely filled with water after rain (Photo by D. Butler).

Figure 3.8. Site 2 crater wetland viewed from the air (Photo by R. Stirnemann).

Figure 3.9. Landing zone near main camp (Photo by D. Butler).

Figure 3.10. Streamside to east of A’opo road end (Photo by K. Swinnerton).

Figure 3.11. Variety of fallen fruit on A’opo lowland forest floor (Photo by D. Butler).

4. RESULTS

Please refer to Appendix 3.1 for thirty minute bird count summaries by site.

4.1 Birdlife:

SPECIES ACCOUNTS

Species are listed in the order adopted by Watling (2001) which he identified as a more natural grouping for non-specialists than standard taxonomic classifications. Those recorded in the uplands, i.e. at over 600m asl. are shown in **green**. Common, Samoan and Scientific names are provided in that order using those used by the IUCN.

For threatened species we list the current IUCN Redlist status and any suggested changes and these are discussed in more detail in section 6. We will also refer to a local assessment of the status of some species in Samoa (Atherton and Tipamaa 2011).

Eastern Reef Heron Matu'u ***Egretta sacra***

Several grey phase individuals seen on coast at Asau and from coastal road to Salelologa.

Pacific Black Duck **Toloa** ***Anas superciliosa***

Two seen flying overhead in area near craters above Asau. One individual arrived at crater '1347' (site 2) after a lake formed there following heavy rain.

Red Junglefowl **Moa'aivao** ***Gallus gallus*** (Polynesian introduction)

One or two birds were heard on different days in forest north of the crater north-east of Mauga Elietoga at about 960m.

Buff-banded **Rail Ve'a** ***Gallirallus philippensis***

Individuals were located at most wetlands in the uplands including swamps within forest flats and craters and a former taro plot at 1030m. on the A'opo trail.

Purple Swamphen **Manuali'i** ***Porphyrio porphyrio***

Single bird seen in Letui on 31st May.

Feral Pigeon **pe palagi** ***Columba Livia*** (European introduction)

Two birds seen on Savai'i on the Patamea road where it drops to the coast near Sapapali'i.

White-throated Pigeon **Fiaui** ***Columba vitiensis***

Seen quite frequently from the lowlands between A'opo and Asau to the uplands particularly along the A'opo trail. Many birds were flushed from the ground, sometimes as pairs, and they showed a tendency to only fly short distances before perching. Most birds were silent. One seen at base camp, the highest elevation present, but not recorded at the two craters in the interior (sites 2 & 3). More numerous at A'opo (20% of 5-minute surveys) than at Asau (3%).

Pacific Imperial-pigeon **Lupe** ***Ducula pacifica***

More often heard than seen, but widespread through uplands. Heard to deliver a variety of calls from 'purrs' to sequences of coos'; one bird seen to do wing clapping displays and on at least four occasions such display heard above the canopy indicating the start of the breeding season. Not recorded at craters in interior, but abundant at A'opo and Asau (57-60% of 30-minute surveys respectively). Four times as many counted as White-throated Pigeon.

Tooth-billed Pigeon **Manumea** ***Didunculus strigirostris***

There was one uncorroborated sighting by one of the team at 1300m on the A'opo trail feeding on *Dysoxylum* fruit. A few loud single calls and one multi-call sequence at two sites could have been made by this species, but it was considered equally likely that they were made by Pacific Imperial-pigeons present in the same specific areas. Large numbers of one of its preferred food, *Dysoxylum* fruits, were seen on the ground at some sites (particularly A'opo trail around 1000m) though only a small proportion of this was ripe, and significant effort was put into searching for birds in these areas. Stirnemann and Harris also made two further visits to the A'opo Road in the weeks following the survey but detected no birds.

It is hoped that the recorders will capture further information on this species. There are concerns over identification of its call – with observers hearing several call sequences that initially appeared similar to Manumea before the bird gave the characteristic 'purr' call of Pacific Imperial-pigeon.

Current Status: Endangered *Suggested Status: Critically Endangered. (See section 5).*

Many-coloured Fruit-dove **Manuma, Manu'ulua** ***Ptilinopus perousii***

Quite uncommon compared to the Purple-capped Fruit-dove with only 4 recorded in 30-minute surveys compared to 121 of the latter. Not recorded at interior craters. As a general observation, became more common towards lower elevations.

Current Status: Least Concern *Suggested Status: Vulnerable. (See section 5).*

Purple-capped Fruit-dove **Manutagi** ***Ptilinopus porphyraceus***

Widespread and relatively numerous in many of the upland areas visited and the most common pigeon/dove which was the only one found at the interior craters. Most abundant at Asau (85% of 5-minute surveys) compared to A'opo (53%) and the craters (26%).

Current Status: Least Concern *Suggested Status: Least Concern.*

Blue-crowned Lory **Segavao** ***Vini australis***

Encountered in larger numbers than expected and typically seen in twos and threes in flight at most sites. Recorded in 84% of 30-minute surveys, most numerous at A'opo and least common at the interior craters.

Current Status: Least Concern Suggested Status: Least Concern.

Long-tailed Koel **'Aleva** ***Eudynamis taitensis***

One bird seen in crater forest north-east of Mauga Elietoga. It is very hard to gauge numbers as the species is silent while on migration in Samoa.

Barn Owl **Lulu** ***Tyto alba***

Seen at two sites: one bird occupying an abandoned taro plantation at 1000m by the A'opo trail and calling frequently at night and one seen flying over the Mauga Mata o le Afi base camp at dusk at 1600m.

White-rumped Swiftlet **Pe'ape'a** ***Aerodramus spodiopygius***

Encountered in good numbers throughout the uplands and particularly active alongside the A'opo trail around 1000m, with slightly lower numbers at the interior craters. No nesting caves detected.

Flat-billed Kingfisher **Tiotala** ***Todiramphus recurvirostris***

Found at various sites throughout the uplands but not the interior craters. Appeared to show a preference for an altitudinal zone between 1000-1200m asl. on A'opo trail and this may be confirmed by data from automatic recorders.

Polynesian Starling **Miti Vao** ***Aplonis tabuensis***

Found throughout the uplands but less conspicuous and numerous than the Samoan Starling. Recorded during 23-33% of 5-minute surveys.

Samoan Starling **Fuia** ***Aplonis atrifusca***

Abundant and active at most sites visited. Movement patterns observed of birds moving to the lowlands in the morning and returning to the uplands in the evening to roost. Over 150 birds observed heading to a roost to the west of the A'opo trail at about 1000m. Recorded during 81% of 5-minute surveys at Asau and 71% at A'opo but only 9% at interior craters.

Common Myna **Maina fanua** ***Acridotheres tristis*** (European introduction)

Jungle Myna **Maina Vao** ***Acridotheres fuscus***(European introduction)

No mynas were observed in the uplands though they were encountered near the coast. Analysis of automatic recorders placed along the A'opo trail should indicate whether, and to what extent, they have penetrated this area and the maximum altitude at which they are currently found.

Red-vented Bulbul **Manu Palagi** ***Pycnonotus cafer*** (European introduction)

Small numbers of bulbuls were observed in the modified upland forests above Asau, where they featured in 15% of 30-minute surveys, but not in the more intact forest further east alongside the A'opo trail or in the interior.

Island Thrush **Tutulili** ***Turdus poliocephalus***

One bird was seen in the west at the crater north-east of Mauga Elietoga and a few counted in that general area, but good numbers were encountered further east particularly along the A'opo trail. They clearly favoured a certain altitudinal zone from c. 1300 m to the cloud forest around Mauga Mata o le Afi where they were abundant. Recorded at 33% of 5-minute surveys at A'opo, 13% at the interior craters, and only 3% at Asau. The species was noisy and conspicuous where it occurred which lends credence to the view that it may be close to extinction on Upolu where there are no recent records despite a recent increase in bird survey activity.

Scarlet Robin **Tolaiula** ***Petroica multicolor***

Widespread throughout the uplands and similarly abundant at all sites (31% of 5-minute surveys at Asau, 33% at the craters and 25% at A'opo). One of the first birds to call at dawn.

Samoan Fantail **Seu** ***Rhipidura nebulosa***

Widespread and relatively common throughout the uplands, fantails were most abundant at Asau where they were recorded in every 30-minute survey.

Samoan Flycatcher (Broadbill) **Tolaifatu** ***Myiagra albiventris***

Broadbills were patchily distributed in particular altitudinal zones but quite numerous where found. They were absent from the interior craters, from the Base Camp and from A'opo Road End but found lower down the road and above Asau. Analysis of the automatic recorders should provide a more detailed picture of their distribution.

Current Status: Vulnerable *Suggested Status: Near Threatened. (See section 5).*

Samoan Whistler **Vasavasa** ***Pachycephala flavifrons***

Encountered widely in relatively small numbers and recorded in half the 30-minute surveys. Most birds were fairly quiet and usually sighted as single individuals.

Polynesian Triller **Miti** ***Lalage maculosa***

Encountered throughout the uplands but most common in the modified forests above Asau (85% of 30-minute surveys there) compared to A'opo (62%) and interior craters (33%).

Samoan Triller **Miti tai** ***Lalage sharpie***

Encountered throughout the uplands and one of the most numerous and conspicuous species at some sites including the scrub and cloud forest around Mauga Mata o le Afi. Recorded during 52% of 30-minute surveys fairly evenly distributed across the three areas.

Current Status: Near Threatened *Suggested Status: Least Concern. (See section 5).*

Samoan White-eye **Matapaepae** ***Zosterops samoensis***

This Savai'i endemic was frequently encountered in small flocks, most commonly in the more modified open forests above Asau. They were confined to the uplands and automatic recorder information may define their lower altitudinal limit. Their presence in 38% of 30-minute surveys including 65% at Asau suggests that the species is present in good numbers and its conservation status should change.

Current Status: Vulnerable *Suggested Status: Least Concern. (See section 5).*

Red-headed (Samoan) parrotfinch[1] Segaula or Manu ai pa'u la'au *Erythrura cyaneovirens*

Parrotfinches are one of the hardest species to detect and less than ten encounters were had. Intact upland forests are not considered a key habitat for this species so the survey was not able to add anything significant to our knowledge of this species and its status. It remains to be determined whether its calls were detected more widely by the automatic recorders.

Current Status: Least Concern (but Conservation Concern in Samoa) Suggested Status: Least Concern.

Cardinal myzomela Segasegamau'u *Myzomela cardinalis*

Encountered throughout the uplands particularly in more open areas and one of the most common species recorded in 86% of 30-minute surveys.

Wattled honeyeater Iao *Foulehaio carunculata*

One of the most common birds throughout the uplands and the first to call at dawn in many sites. Recorded in almost every 30-minute survey (96%) at each site.

Mao Ma'oma'o *Gymnomyza samoensis*

Mao were not distributed continuously throughout the uplands. They were not recorded in the disturbed forests above Asau and were only found on a limited altitudinal range on the A'opo trail – details to be confirmed by automatic recorders. Three fledglings were recorded in total during the survey. Since the fledgling (pairs have only a single chick) is fed by the female bird for two months after leaving the nest this suggests that birds were reproductively active in May, April or March. Often the first species to start singing at dawn, or prior to dawn, birds were also heard calling at intervals during the night at the Base Camp.

Current Status: Endangered Suggested Status: Endangered

Tahiti Petrel Ta'i'o P ***seudobulweria rostrata***

One bird was recorded calling at night within the forest of crater '1347' and observed sitting on a flat ledge of bare soil in front of a tree root mass created by several overturned trees. Its distinctive calls were captured on an automatic recorder and identification confirmed by comparison with recordings on the internet from American Samoa. This represents the first record of this species on land and presumably breeding in Samoa although several thousand pairs are known to breed in American Samoa (O'Connor and Rauzon 2004). Birdlife International's factsheet for the species identifies that breeding appears to occur throughout the year, although on American Samoa at least, there seems to be a peak around November (O'Connor and Rauzon op. cit.). Eggs are laid in burrows on rocky slopes or in open upland forest. In New Caledonia, most of the recently discovered colonies are small (<10 pairs). This bird seems to have been alone and no other calls were heard though automatic recorders set in the area have yet to be checked. The area held lots of hollows that potentially could be developed into breeding burrows but none were seen in a short check. It seems that it was either an early arrival ahead of breeding or a late departing bird post-breeding from a small colony, and the former may be more likely based on the American Samoa data.

Current Status: Near Threatened Suggested Status: Near Threatened

Buller's Shearwater *Puffinus bulleri*

A small number of petrels/shearwaters were observed flying west to east from the Upolu to Savai'i ferry on 16 and 31st May. Two observers had clear views of a bird close to the boat on the 31st and identified it as this species based on the distinctive over-wing pattern. Buller's shearwaters have been seen before in Tongan and Fijian waters but not previously in Samoa's. They breed only on the Poor Knights in northern New Zealand and migrate to the northern Pacific and are considered a vagrant in the south Pacific (Watling 2001).

Current Status: Vulnerable

White-tailed Tropic-bird Tava'e *Phaethon lepturus*

Tropic-birds were observed flying above the forest in small numbers in several different areas. No birds were seen within the forest itself (where they breed in holes) so they were not breeding at this time.

1 Some ornithologists consider the Samoan bird to be a sub-species of the red-headed parrotfinch which is also found in Fiji. Its taxonomy needs to be resolved.

White Tern **Manusina** ***Gygis alba***

White Terns were observed flying above the forest in greater numbers than tropic birds in several different areas. No birds were seen within the forest itself (where they lay single eggs on branches with no nest) so they were not breeding at this time.

Brown Noddy **Gogo** ***Anous stolidus***
lack Noddy **Gogo** ***Anous minutus***

Noddies were observed flying above the forest in many areas and a concentration of birds was seen flying overhead at dawn and dusk at site 3. This concentration suggests that breeding might be about to start. These were not generally identified to species but those that were closely observed were Brown Noddy which is by far the more common of the two in Samoa.

Figure 3.12. Ma'oma'o (captured on Upolu) (Photo by D. Butler).

Figure 3.13. Manumea (in captivity in 1970s) (Photo by B. Gillespie).

Figure 3.14. Red-Headed (Samoan) Parrotfinch (Photo by R. Stirnemann).

Figure 3.15. Cardinal Myzomela (Photo by R. Stirnemann).

Figure 3.16. Flat-billed Kingfisher (captured on Upolu) (Photo by R. Stirnemann).

SPECIES NOT RECORDED

White-browed Crake **Vai** ***Porzana cinereus***

Spotless Crake **Vai (?)** ***Porzana tabuensis***

No confirmed records though some calls at crater '1347' (site 2) could have been made by crakes and two feathers picked up there could possibly be from the White-browed Crake. Analysis of these and sound recordings will be needed before any definite information can be provided.

Samoan Moorhen **Puna'e** ***Gallinula pacifica***

No possible sightings and no calls attributable to this species were heard. Analysis of sound recorders needs to be completed before a final assessment is done.

Current Status: Critical.
Suggested Status: Critical or Extinct

Shy Ground-dove **Tuaimeo** ***Gallicolumba stairii***

No possible sightings or calls heard. Not easy to detect but considered absent from areas visited.

Current Status: Vulnerable.
Suggested Status: Threatened in Samoa

Breeding observations:

Many passerines were observed to be breeding. Scarlet Robins and Polynesian Trillers were seen on nests and the following species were seen with fledged young: Polynesian Starling, Samoan Starling, Samoan Fantail, Scarlet Robin, Samoan Whistler, Samoan Triller, Samoan White-eye, Cardinal Myzomela, Wattled Honeyeater, Mao. Samoan Starlings were seen to be moulting. Samoan Whistler seemed unusually quiet which might relate to a particular stage in their breeding season.

It appeared that the breeding season was just starting for pigeons and doves with one nest seen and wing-clapping of Pacific Imperial-pigeons recorded several times towards the end of the survey. White-throated Pigeons were not heard calling at all. One immature was seen with a pale grey throat and dull red-brown bill that was considered a bird from the previous breeding season.

Seabirds were not apparently nesting. White Terns, White-tailed Tropicbirds and noddies were seen flying over the forest but not landing within it. The single Tahiti Petrel seen was not apparently occupying a burrow at this time.

Diurnal movements:

Samoan Starlings were observed moving in large numbers from night-time roosts in the uplands towards the coast in the morning and back in the evenings. Many of the Pacific Imperial-pigeons and Blue-crowned Lory seen were also flying fairly directly towards the coast in the mornings. Blue-crowned Lories were also seen in good numbers on the A'opo trail flying back from the coast in the evenings.

4.2 Mammals

NATIVE SPECIES:

Samoan Flying-fox **Pe'a** ***Pteropus samoensis***

Pacific Flying-fox **Pe'a** ***Pteropus tonganus***

Flying foxes were rarely encountered in the uplands. Single Samoan Flying-foxes were seen in the day on several occasions. Numbers of Pacific Flying-foxes were seen at the base camp at Mata o le Afi at dusk and early in the morning and they were heard at the road end on the A'opo trail. Higher numbers of this species were seen on the coast at Asau in the evenings. No roosts were observed during the helicopter reconnaissance.

INTRODUCED SPECIES:

Rats **Isumu** ***Rattus spp.***

Snap traps were set for rats at 4 sites, baited with processed meat or roasted coconut: along the ridge from the TV tower at site 1; above the camp site at the A'opo road end and at two locations around the base camp. No rats were caught in c.100 trap-nights and almost no bait taken.

Pacific rats were observed on two occasions on the A'opo trail below the road end and one was caught on a glue trap set for reptiles. Rat hairs were also found on several other glue traps.

Feral cats **Pusi** ***Felis catus***

Two feral cats were seen at base camp one black and one tabby. Scats were seen frequently on the upper parts of the A'opo trail and found to contain rodent hairs and bones and bird feathers including those of the Blue-crowned Lory. Fresh cat prints were found in wet mud on the upper parts of the A'opo trail.

Feral Pigs **Sua** ***Sus scrofa***

Pig droppings and feeding signs were seen at most sites. Two pigs were observed at Site 3, while a pig was observed crossing the trail to Mauga Silisili base camp at c1500m asl.

Feral Cattle **Povi** ***Bos taurus***

Significant numbers of feral cattle were present at site 1 where their trampling had kept open grassy areas within forested flats and had a polluting effect on wetlands.

4.3 Invasive plants

Teams were disappointed to find the extent to which weeds had invaded the uplands including the remote craters accessed by helicopter. Coster's Curse or la'au lau mamoe (*Clidemia hirta*) was one of the most damaging covering many open areas where it made progress difficult and was common on the fringes of the wetland in crater '1347'. A variety of weeds had made their way up the A'opo road.

5. DISCUSSION

Overall Findings

There had been some expectation that the Savai'i uplands was a large, remote area where human impact would be slight and the native fauna thriving. While some bird species were found to be widespread and abundant, the rarer species were not as abundant as had been hoped despite the presence of large areas of apparently suitable habitat. Clearly the uplands fauna have not escaped the threats posed by invaded animals. These forests may not provide year-round habitat for some of the more mobile species such as pigeons and doves that follow the fruiting of different trees, and the significant loss of the lowland forests has probably been critical for them.

The survey showed that some threatened species were found in good numbers in the uplands whereas this was not the case for others. This leads to some suggested changes in status below. The survey located no sign of the Samoan Moorhen or Puna'e so lends further support to the view that this species is extinct. It has raised major concerns of the status of the Tooth-billed pigeon or Manumea, confirmed the patchy distribution of the Mao or Ma'oma'o, and suggested that there are good numbers of the Samoan white-eye or Matapaepae.

We identified that some forest species were most abundant in a particular habitat or altitudinal range (noting that these two are clearly linked). Examples were the Island Thrush, Silvereye, Mao, Kingfisher and Samoan Flycatcher (Broadbill). Whether these represent preferred habitats or the current 'refuges' of species that were once more widespread (due to lower number of predators in these for example) would require more detailed assessment. With the finding of Tahitian petrel the potential for significant seabird breeding colonies is realised and this will be important to survey.

Survey coverage

The survey only visited half the areas that were initially planned. It became evident during the helicopter reconnaissance that there were a limited number of open areas, typically crater wetlands, where teams could be dropped in. This coupled with bad weather that reduced the flying meant that the initial target was too optimistic. However we did sample a good range of sites including two craters in the interior that are unlikely to ever have been visited before.

Flying over the uplands one gains the impression of a series of 'islands' (craters) set in a flat 'sea' of forest. These islands are likely to be of particular significance for the avifauna as they offer a greater diversity of habitats including lakes and swamps, provide a greater range of topography including slopes of different aspect that may hold more soil for burrowing, and because of this topography may hold higher quality forest protected from cyclones. Cyclones Ofa (1990) and Val (1991) the most devastating cyclones in over a century had dramatic impacts on Savai'i's forests, partly because they followed so closely together. A study at Tafua Peninsula in the lowlands showed 53% tree mortality (Elmqvist *et al* 1994) and upland areas were also severely affected. Much of the survey area is considered to still be recovering from these events making the craters potentially more significant.

Reviewing the 1: 50,000 scale maps suggests that there are over 100 such craters or hillocks above the 600m contour. However only around 20 appear to hold non-forest vegetation and the survey was able to visit six of these (four through the use of helicopters). A further nine were considered accessible by helicopter, with the remainder either too small or too deep for landing.

Seasonality is another coverage issue. The survey was originally planned for June nearer the middle of the dry season but was moved forward due to the availability of helicopters which made a huge difference to the logistics. Relatively little is known of the breeding season of Samoa's birds. Our evidence was that most passerines were in the key part of their season, with many fledglings noted as following adult birds, most pigeons and doves were just beginning, and seabirds were not breeding. The survey thus worked well for passerines; a few weeks later might have been better for pigeons and doves which would then be more active and vocal; either earlier or later may have been more useful for detecting seabirds.

A broad, rapid biodiversity survey like the BIORAP inevitably has to make compromises in both coverage and timing. Follow-up surveys can be more specifically designed to target particular groups of species.

Variation between sites

The avifauna survey visited three different areas:

1. above Asau from 900m to 1040m, impacted by past forest clearance, some plantation establishment, significant weeds and feral cattle
2. above A'opo alongside the recently-established road, from 800m to clear tops at c.1800m, subject to less human impact but under immediate threat
3. in the interior from 1280 to 1370m where human impact was expected to be minimal.

Area 1 held higher numbers of Samoan White-eyes and Purple-capped Fruit-doves than the other two sites but lower numbers of pigeons than at A'opo and no Mao. This suggests that its more modified nature made it less suitable for more specialist species that depend on a diversity of large native trees. Area 2 held the highest numbers and diversity of birds, due in part to the diversity of habitats encountered over its larger altitudinal range. Area 3 held fewer pigeons and doves than the other sites but was the only site where a burrow-nesting seabird was detected.

Comparison with previous surveys

The 1996 survey of Samoa's upland ecosystems spent 4 days in the field in Savai'i during May and 9 days there in July-August (Schuster *et al*., 1999). This included 1½ days around Mauga Maugaloa above Asau in August (our Area 1) and 6 days between A'opo and Mauga Silisili (over both periods) (our Area 2). This survey was based on 5-minute point counts which were not used in 2012 due to their variability but some comparisons can be made (Table 3.1).

Table 3.1. Comparison between 1996 and 2012 bird surveys

Site	1996	2012
Area 1 **(Above Asau)**	▪ Tooth-billed Pigeon and Mao present. ▪ 'Surprisingly high' numbers of Samoan White-eye. ▪ Pigeons & doves 'not numerous'. Pacific Imperial-pigeon only in the lower altitude counts (750m) and not at higher (1000m) ▪ Red-vented Bulbul not recorded.	▪ Tooth-billed Pigeon and Mao not recorded. ▪ Highest numbers of Samoan White-eye of all sites surveyed. ▪ Purple-capped Fruit-doves relatively numerous compared to pigeons ▪ Red-vented Bulbul present.
Area 2 **(A'opo trail to Mauga Silisili)**	▪ Shy Ground-dove present. ▪ Tooth-billed Pigeon recorded averaging 0.6/count. ▪ Purple-capped Fruit-doves c. 3 times more numerous than Many-coloured Fruit-doves (averaging 1.27 and 0.47 / count respectively)	▪ Shy Ground-dove not recorded. ▪ Only 1 uncorroborated sighting of a Tooth-billed Pigeon. ▪ Purple-capped Fruit-doves very much more numerous than Many-coloured Fruit-doves (121 and 4 counted during 30-minute surveys respectively)

This comparison suggests a deteriorating situation for the rarer birds (Tooth-billed pigeon, Mao and Many-coloured Fruit-dove) over the 16-year period, together with an increase in the range of one invasive alien species, the Red-vented Bulbul. A number of reasons for this can be suggested. Site 1 was already significantly modified in 1996 and the lack of much intact forest will have facilitated the increasing impact of invasive plants and animals. People, particularly hunters, are likely to have made continual use of the area, particularly as good access has been maintained with the construction of the TV tower.

Human disturbance has increased more recently in Area 2 with the construction of the road (see later). But it is likely that some of the species there, particularly the pigeons and doves, have been most affected by the significant logging of lowland forest between Sasina and A'opo over the last c.15 years. These forests were listed as one of only five Grade 1 sites in the lowland ecological survey of 1989 (Park *et al.* 1992) and singled out as the area best capturing the natural ecology of the lowlands. Despite this, and Forest Policies that sought to phase out logging years ago, most have now been logged[2].

Suggested changes of status

The survey's findings have led to several suggestions for changes, each of which will be evaluated in more detail with the assistance of Birdlife Pacific against detailed IUCN Red List criteria.

Species considered for change to a more threatened status:

- Tooth-billed Pigeon – Endangered to Critically Endangered
- Many-coloured Fruit-dove – Least Concern to Vulnerable (It seems unlikely that the status of the species would be changed in this way as it is also present on Fiji, Tonga and American Samoa. However it seems to clearly be 'vulnerable' in Samoa though the cause of its ongoing decline is unclear.)

Species considered for change to a less threatened status:

- Samoan Flycatcher (Broadbill) – Vulnerable to Near Threatened
- Samoan Triller – Near Threatened to Least Concern
- Samoan White-eye – Vulnerable to Near Threatened

2 By the same company whose vehicles we hired which was rather disappointing.

6. CONCLUSIONS AND CONSERVATION RECOMMENDATIONS

6.1 Further surveys

This survey provided a snapshot of the avifauna and further work is needed to establish a fuller picture to aid site conservation and management. Further surveys should aim to:

1. Cover areas not visited during this survey

The four areas identified as priorities in the initial work plan which could not be accessed are as follows (including comments on access from that plan, and site numbers from recommendations of Atherton & Tipamaa (2011) which were largely based on the previous upland survey report (Schuster *et al*. 1999):

Eastern central sites e.g. Mauga Mafane, Mata'ulano, To'i'avea, Lakes Mafane and Mata'ulano

Diverse habitats in part of the large area listed as the priority for survey. Site 5 'recommended study areas on Savai'i' is described as 'located in the montane rainforest on the SE slopes of the central mountain plateau in the vicinity of Mauga Mafane at approx. 900m asl.'

Probable access: The main trail or southside leg may provide access to some sites (note: a team of birdwatchers visited Mauga Mafane with a local guide in 1979 but whether trails still exist to here following the cyclones of 1990/91 is unknown). However it is hoped that helicopter will be possible to several areas such as swamps in craters. Ideally a team would be dropped at a location for a day and a night (or two), then moved to another location.

North-eastern sites e.g. Mauga. Maugaloa and Mulimauga or east of these

A further part of the priority area. Site 4 'recommended study areas on Savai'i' is described as 'located on the NE slope of the central mountain plateau between 900-1200m elevation where montane forest meets cloud forest'.

Probable access: Either access from plantation roads to Mauga Matavanu, but then quite a length of trail may need cutting, or helicopter if open sites can be identified.

Gataivai River Catchment – site 6 'recommended study areas on Savai'i'

Mittermeier tried searching this area for puna'e in 2005 but found the terrain limited the work.

Probable access: Access may be difficult and this area might be left out unless a helicopter drop-off can be identified.

Uplands between A'opo and Asau

Site 2 'recommended study areas on Savai'i' is described as on NW slope of central montane plateau at 900-1200m. and includes a variety of ecosystems from montane rainforest to volcanic succession. This site lies between areas previously surveyed above Asau and above A'opo – and between two possible sightings of puna'e. However it may be that its forests are still in a relatively early stage of succession and thus of reduced priority for survey.

Probable Access: This site may only be included if suitable access can be identified, or if a priority for plant work.

2. Focus on craters with diverse habitats

Brief visits to several such sites located a Tahiti petrel and indications of the presence of rails and crakes. The Puna'e could also have occupied wetlands such as those found in craters. If helicopters are available a future survey should aim to visit the other accessible ones and spend more time in those visited. The ideal time of year could be determined in relation to likely seabird breeding seasons.

3. Focus on specific species or groups

There is an urgent need for more survey work on the tooth-billed pigeon (see below) which seems likely to require significant management to save it from extinction.

Samoa's NBSAP (Government of Samoa 2001) includes an action 'Carry out a survey to determine the status of

Samoa's seabird population'. This could now be considered more important following the lack of seabirds found during this survey and the fact that two species identified have not apparently been recorded in Samoa before.

6.2 Conservation of tooth-billed pigeon – Manumea

The results of this survey, coupled with observations from Upolu where the species has proved hard to locate at previous sites, suggests this species to be in a critical situation. The immediate priority is further survey work on Upolu where it is hoped that birds can still be found in some of the relatively accessible sites identified in the species recovery plan (MNRE 2006). Such sites potentially lend themselves to the kind of management interventions that may be needed to bring about any recovery.

6.3 Conservation of Mao – Ma'oma'o

While Mao were recorded at several sites this does not significantly change the picture for this species. Their presence does not mean that the population is doing well. Research on Upolu is showing that many pairs are still not successfully producing enough chicks due to the high predation rate on nests. In addition, it appears that the female Mao are disappearing potentially due to rat predation on the nest potentially resulting in a skewed sex ratio. This may then result in a particularly loud male being present in a territory impacting on presence and absence surveys but increasing detectability. The loss of an adult female has a much higher impact on the population growth than chick loss.

However the survey has clarified that, for the Mao, protecting upland areas is likely to help maintain this species in Samoa.

6.4 Conservation and management of the Savai'i Uplands

The Savai'i uplands are a large area of relatively intact forest that is important to the conservation of the country's birdlife. The aim must be for them to be managed in a way that puts conservation as a priority, which largely means protecting them from negative impacts caused by people. Difficulties of access do mean that much of the area is not visited by people, but we have seen with the illegal A'opo 'road' how this can rapidly change.

Just ensuring that the forests remain intact may not be enough to conserve some of the bird species using the area. Active management such as the control of invasive species may be needed, but unless the forest is retained this will never be an option.

Conservation of the uplands needs to be advocated at two levels. Firstly, and arguably most importantly, it needs to take place with the local communities who communally own the uplands. Secondly it needs to occur at Government level and bring in the support of the international community. Over the past 20 years we have seen many different approaches applied to the conservation of forested lands in Samoa including the creation of national parks and reserves, the establishment of rainforest preserves with international funding, working towards the development of community-based conservation areas such the South Pacific Biodiversity Conservation Programme, and trying to establish businesses such as ecotourism to make non-destructive use of forests. Any positive outcomes have generally not been sustained. We recommend that a process is established to review these different approaches, both in Samoa and the wider Pacific, identifying their strengths and weaknesses, to come up with some new ideas.

However conserving the uplands alone will not ensure the conservation of the country's birdlife. Our results suggest that the emphasis placed on the conservation of lowland forests over the past 25 years was appropriate and is still vital. Several bird species were seen making daily movements from the uplands to feed in the lowlands and others are expected to make seasonal movements between the two areas following the flowering and fruiting of different trees. Conserving the uplands alone is not going to save the Tooth-billed Pigeon as a key example.

The conversation with village communities should seek the conservation of remaining lowland habitats and a commitment to largely leave the uplands alone, and support to obtain the best possible return from already modified lands where the forest has been cleared.

A'OPO 'ROAD'

The road that has been bulldozed into the cloud forests above A'opo, apparently illegally with none of the required consents, is considered a significant threat to the biodiversity of the uplands. It provides a route for invasive species to colonise the area and we noted feral cats and weed species as already taking advantage of it (refer Figures 3.17 and 3.18).

Figure 3.17. Spread of weeds up A'opo 'road' (Photo by D. Butler).

Figure 3.18. Cat scats on A'opo 'road' (Photo by K. Swinnerton).

In time we would expect invasive mynahs and bulbuls to move up into areas above their current range. It increases the chances that people will start to have a more damaging impact in the uplands through hunting – White-throated Pigeons are particularly vulnerable according to our observations – and potentially logging and fire. We also observed litter, and graffiti cut into lichen that will take many years to recover.

We recommend that the use of the road is controlled and restricted by A'opo village and that a logging ban is put in place along it. It can be an asset to the village by facilitating access for tourists. But visitors will not wish to go there if they see litter, graffiti, logging of trees, and spread of pests. Social media and the internet now provide rapid opportunities for negative feedback to spread that would result in visitors avoiding the area.

The Government should take action to address the illegal construction of the road to prevent other villages undertaking such destructive activity elsewhere.

ACKNOWLEDGEMENTS

The avifauna team acknowledge particularly the support of Bruce Jefferies, Project Manager, and James Atherton who played a major role in coordinating the surveys. So'oalo Tito Alatimu, Suemalo Talie Foliga, Sue Mulvany, provided logistical support along with those who established and provided food at the base camp. We thank the other teams for their enthusiasm and companionship. The helicopter crews of the NZ Defence Force did a sterling job of reconnaissance and dropping off and picking up teams in very difficult circumstances. Stu Cockburn of the New Zealand Department of Conservation organised the design and supply of the automatic sound recorders and we acknowledge Gerry Kessels (Kessels & Associates) who loaned us several that he had purchased.

Birdlife Pacific, Island Conservation, Conservation International all allowed staff to participate in the survey and provided their salaries and this support was vital to the success of this work.

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Appendix 3.1. Thirty minute bird count summaries

Table A: Counts of rarer species

		Nos. counted				Nos. counted/count			
Common name	**Samoan name**	**Asau (Site 1)**	**Craters (Sites 2 and 3)**	**A'opo Trail**	**Total**	**Asau (Site 1)**	**Craters (Sites 2 and 3)**	**A'opo Trail**	**Total**
	No. of counts	20	9	21	50	20	9	21	50
Tropicbird	Tava'e'ula	1	0	0	1	0.1	0	0	0
Brown Noddy	Gogo	0	0	0	0	0	0	0	0
White Tern	Manusina	1	0	7	8	0.1	0	0.3	0.2
Banded Rail	Ve'a	1	2	0	3	0.1	0.2	0	0.1
White -throated Pigeon	Fiaui	4	0	19	23	0.2	0	0.9	0.5
Pacific Imperial-pigeon	Lupe	19	0	68	87	1	0	3.2	1.7
Many-coloured Fruit-dove	Manuma	3	0	1	4	0.2	0	0	0.1
Purple-capped Fruit-dove	Manutagi	64	12	45	121	3.2	1.3	2.1	2.4
Blue-crowned Lory	Sega vao	44	14	113	171	2.2	1.6	5.4	3.4
Island Thrush	Tutumalili	1	7	40	48	0.1	0.8	1.9	1
Samoan White-eye	Matapapae	20	2	9	31	1	0.2	0.4	0.6
Mao	Ma'oma'o	0	6	13	19	0	0.7	0.6	0.4

Table B: **Presence/absence (P/A) of all species recorded in counts**

		P/A Species per 30min Survey				Percent of 30min surveys with species			
Common name	Samoan name	Asau (Site 1)	Craters (Sites 2 and 3)	A'opo Trail	Total	Asau (Site 1)	Craters (Sites 2 and 3)	A'opo Trail	Total
	No. of counts	20	9	21	50	20	9	21	50
Tropicbird	Tava'e'ula	1	0	0	1	5%	0%	0%	2%
Brown Noddy	Gogo	0	0	0	0	0%	0%	0%	0%
White Tern	Manusina	1	0	3	4	5%	0%	14%	8%
Banded Rail	Ve'a	1	1	0	2	5%	11%	0%	4%
White -throated Pigeon	Fiaui	3	0	7	10	15%	0%	33%	20%
Pacific Imperial-pigeon	Lupe	12	0	12	24	60%	0%	57%	48%
Many-coloured Fruit Dove	Manuma	2	0	1	3	10%	0%	5%	6%
Purple-capped Fruit-dove	Manutagi	20	4	13	37	100%	44%	62%	74%
Blue-crowned Lory	Sega vao	16	6	20	42	80%	67%	95%	84%
White-rumped Swiftlet	Pe'ape'a	14	4	17	35	70%	44%	81%	70%
Flat-billed Kingfisher	Ti'otala	1	0	11	12	5%	0%	52%	24%
Polynesian Triller	Miti tai	17	3	13	33	85%	33%	62%	66%
Samoan Triller	Miti	12	4	10	26	60%	44%	48%	52%
Red-vented Bulbul	Manu palagi	3	0	0	3	15%	0%	0%	6%
Island Thrush	Tutumalili	1	4	15	20	5%	44%	71%	40%
Samoan Fantail	Se'u	20	6	12	38	100%	67%	57%	76%
Scarlet Robin	Tolaiula	13	8	11	32	65%	89%	52%	64%
Samoan Flycatcher (Broadbill)	Tolaifatu	6	0	1	7	30%	0%	5%	14%
Samoan Whistler	Vasavasa	11	4	10	25	55%	44%	48%	50%
Samoan White-eye	Matapapae	13	2	4	19	65%	22%	19%	38%
Cardinal Myzomela	Segasegamau'u	20	8	15	43	100%	89%	71%	86%
Wattled Honeyeater	Iao	19	9	20	48	95%	100%	95%	96%
Mao	Ma'oma'o	0	5	9	14	0%	56%	43%	28%
Red-headed Parrotfinch	Segaula	2	2	0	4	10%	22%	0%	8%
Polynesian Starling	Fuia Vao	14	6	14	34	70%	67%	67%	68%
Samoan Starling	Fuia	20	3	20	43	100%	33%	95%	86%
Others – Red Jungle Fowl	Moa	2	0	0	2	10%	0%	0%	4%

CHAPTER 4
Report on the moths and butterflies (Lepidoptera) of Upland Savai'i

ERIC EDWARDS

Team Members: Elisala Ilaoa (MNRE), Warren Chinn (NZ DOC), Fred Brook (Consultant, mostly snails) and much casual assistance from the other teams including local and national BIORAP expedition support.

1. INTRODUCTION

Savai'i is a high volcanic island that formed over several millions of years by predominantly basaltic eruptions. Being part of the Samoan Islands it supports a rich biota of plants and animals, many of which have biogeographic relationships with the Tongan and Fijian archipelagos, and with Papua New Guinea, Australia and Indo-Southeast Asia (Tams 1935, Robinson 1975, Holloway 1983, Miller 1996, Munroe 1996). However, many moth species are not found among the many Pacific islands eastward of the 'Samoas' (Robinson 1975, Holloway 1983). Savai'i is the largest of three relatively large islands in Samoa (including Upolu and Tutuila), with an area of ~1700 square kilometres, and an extensive core central upland and high point 1860 metres above the sea. A rich human history retains strong cultural ties to a great raised mountainous ridge (shield volcano) shown on maps dense with indigenous place names (Bier 1990, DLSE Samoa 2000). However, merchantable timber and other resources are not to be found above ~800-900 metres and thus without tracks and infrastructure the uplands have remained poorly explored or reported for invertebrates and other wildlife. In May 2012 a biological survey –BIORAP completed extensive sampling of vascular plant-life, terrestrial snails, insects and vertebrate animals –mostly birds. The Critical Ecosystem Partnership Fund (CEPF) supported a partnership between the Secretariat for the Pacific Regional Environment Programme (SPREP), the Ministry of Natural Resources and Environment (MNRE) and local communities on Savai'i, to investigate and describe the upland biota, and recommend appropriate conservation actions.

This report focuses on the Lepidoptera fauna, namely moths and butterflies. It identifies values, landscape ecology and threats, and suggests management implications that can be shared with local community leadership.

The cataloguing of Samoa's insects began during German colonial trading and resulted in species such as the Large Swallowtail butterfly (pepe ae) being named –*Papilio godeffroyi* (Semper 1866). Serious collecting was pursued in the 1920s with The British Museum (Natural History) London commissioning and undertaking to interpret collections and revise all insect groups. Twenty five publications spanned 1927 to 1935. Four important works on butterflies and moths are cited here including (Hopkins 1927 –butterflies; Meyrick 1927 –micro-moths; Prout 1928 –Geometrid moths; and Tams 1935 –remaining large bodied moth groups). Useful works that have followed since then include Comstock (1966), which focused on American Samoan fauna, and Robinson (1975), which detailed the Fijian Macro-Lepidoptera and Lepidoptera relationships among Pacific Islands. Tennant (2006) revised and updated checklists of Pacific region butterflies, and Edwards (2010) produced a Samoan butterfly catalogue.

The history of collecting Lepidoptera – moths at higher altitude anywhere in Samoa is very limited. Malololelei at 2,000 feet (~600 metres asl.) on Upolu is a frequently cited locality in Samoan moth taxonomy. It is the highest elevation (or the only elevation) recorded for many Samoan species and is approximately associated with the highest point on the Cross Island Road which climbs from Apia (North Coast) across to the South Coast.

Focus of the project (SPREP/CI 2012 Savai'i BIORAP agreement):

1) Use surveys to make contributions towards the conservation and management of the Upland Savai'i Key Biodiversity Area (KBA, see CI, MNRE & SPREP 2010) by providing critical biodiversity data that will assist in determining and prioritizing specific areas, within the KBA, that will require particular conservation management attention.

2) Collect information on butterflies – including potentially locating the Samoan swallowtail, which is considered close to extinction.
3) The overall objective of the BIORAP is: To enhance knowledge of the status of the biodiversity of the upland forests of Savai'i and to establish immediate and long-term plans for its conservation.
4) To survey and report on invertebrates with a focus on Lepidoptera –moths & butterflies. Make observations of introduced / invasive species and other threats to the conservation of the upland forests of Savai'i.
5) Protection and conservation management policies and sustainability options developed: Interpret a set of recommendations from the survey results highlighting key management and policy options that the Government and local communities should consider to protect the upland forests of Savai'i, including key species found therein.

2. LOCATIONS AND METHODS

Two main locations were surveyed for insects during the BIORAP. In the hinterland of A'opo Village a camp was established at Mata o le Afi at 1640 m asl (LAT. 13°35.51′ S, LONG. 172°30.49′ E). (Figure 4.1), which provided access to both a range of habitats and an altitudinal sequence. Habitats included montane forest, cloud forest, lava field rubble/volcanic scrub and *carex* bog (see Figure 4.2, habitats well detailed in Whistler 1978). No streams or ponded water habitats were available in the area to sample. The altitudinal sequence (See Appendix 4.3 map grid references) extended from the Mauga Silisili high point ~1860 m asl. to the camp at 1640 m asl. and then down an access track that arises from the A'opo –Asau road at ~200 m asl.

Figure 4.1. Location of Moths/Lepidoptera survey sites

Figure 4.2. Crater raised peatland with lag zone *carex* bog. Wetland 1720 metres asl. near Mauga Silisili 13°36.35′ S, 172°29.33′ E. Habitat for endemic moth *Glaucocharis dialitha* (Crambidae see figure 4.7.). Vao fulu –kosters curse or other weeds were not found here (Photo by E.Edwards).

The second location is within the remote uplands of Palauli le Fālefā district. It comprised a weathered, composite scoria cone complex near the upper eastern margin of the spectacular Vanu Tausala gully system that drains out to the middle of Savai'i's south coast. This location (LAT. 13°38.59′ S, LONG. 172°24.72′ E), referred to here as South crater Mauga Te'elagi, had a floor elevation of 1360 m asl. (Figure 4.1), and included ~5 hectares *carex* sedge-dominated swampland, and an area of fen containing shrubland. Crater slopes and adjoining areas are clothed in diverse montane forest rather than cloud forest. The enclosing moderately steep slopes have deep clay soils with exposures of weathered basaltic lava extending to a ridgeline averaging about 50 metres above the floor. Wetland vegetation is dominated by clumpy pedicle sedges and some grasses with an area of wet shrubland. The invasive shrub vao fulu (Kosters curse *Clidemia hirta*, see Whistler 2002) is scattered throughout the wetland and forms dense patches adjoining the slope margins. Low mixed forest has abundant oliolī –*Cyathea* species tree ferns and a rich complex of mossy hardwood trees including *Weinmania affinis*, *Spiraeanthemum samoense*, *Schefflera samoensis*, maota mea *Dysoxylum huntii* and many others. On sunny ridges vī vao *Reynoldsia pleiosperma* was also present. The high proportion of tree ferns may have been evidence of 20 year old cyclone damage, and some local pig rooting was noted. Permanent surface water streams flow in the area but could not be surveyed for stream insects under the conditions of the survey.

Collections

The rapid inventory targeted moths and butterflies while also collecting other insects, spiders and invasive ants for later analysis and reporting elsewhere. Collections will eventually be housed in the New Zealand Arthropod Collection (NZAC) in Auckland with most material presently held by the author for analysis and determination of new species. NZAC is an institutional insect collection that specialises in Samoan and other Pacific Island insects –mostly Lepidoptera (i.e., moths and butterflies). Some of the material can potentially be studied in association with other institutions that maintain a specialist storage facility. These could include (among others) University of South Pacific Suva Campus Herbarium in Fiji and the Bishop Museum in Honolulu.

Process of identifying taxonomic richness of Lepidoptera

Identification of taxa curated from the expedition was carried out by comparison with other collections and by use of published works for Samoa and Fiji (eg. Tams 1935, Comstock 1966, Robinson 1975, Clayton 2012), and keys to Lepidoptera families (Dugdale 1988, Nielsen & Common 1991). Many species are new to science or, in a few cases could only be determined by detailed comparison with original Type specimens kept in the British Museum of Natural History (applies particularly to small moths –see Meyrick 1927). Such 'species' have been listed as un-named or 'tag named' taxa and are given a numerical code in the attached Appendix 4.1. Endemic moths are species including tag named taxa not known elsewhere beyond the Samoan Islands or more accurately, not known by the author elsewhere. Some caterpillar host plant associations were drawn from literature (including those listed above, Swezey 1942, Sutrisno & Horak 2003), as well as online databases, Herbison-Evans & Crosley (2012), Robinson *et al*. (2012). Family nomenclature for moths follows Van Nieukerken *et al*. (2011).

Sampling methods

Three methods were used to sample moths, other insects and spiders. Hand collecting occurred in all sites, and insect malaise trapping and insect light trapping were carried out at the two camps only. Along the Mata o le Afi access road, ants were also recorded from sticky traps used to survey lizards (reported, R. Fisher elsewhere in this report).

Simple hand collecting techniques were based on observing insects in a range of habitats and capturing samples in small plastic jars for later curation. A sweep net was also used aerially or through vegetation to capture beetles, bugs, flies and moths. Observations were made during the night as well as in daylight.

Insect malaise traps are suitable for sampling a great range of very mobile insects and spiders during the day or night in relatively sheltered but open areas associated with forest margins. The trap is made from a fine mesh in a tent shape and is similar in size to an actual two person tent. It traps insects that fly into the mesh and then walk up through a mesh funnel where they fall and accumulate in a preservative solution. Malaise traps can be set in place for several days with sampling jars replaced every two to three days in the cool upland conditions. These were established near the Mata o le Afi Camp near forest edges and also at the crater south of Mauga Te'elagi.

Insect light trapping is done in relatively calm conditions, beginning at dusk for about three hours depending on the temperature. In cooler temperatures often but not always experienced in uplands, insects are less active and the sampling time is shorter. A powerful 240 volt 120 watt mercury vapour ballasted ultraviolet light powered by a portable generator was used to attract moths (Figure 4.3 and Figure 4.4). A large white sheet is placed on the ground and the light placed in the middle. Expedition team members captured specimens of as many moth species as possible individually in small plastic jars to be later preserved and identified. A few wasps, flies, beetles, cicada and aquatic insects where present can also be expected to fly close into the light and land on the sheet.

Figure 4.3. Lesser marbled hawkmoth *Daphnis placida* attracted to the light at Mata o le Afi Camp 1640 m (Photo by Eric Edwards).

Figure 4.4. Moths at light trap. 1360 m asl. Crater south of Mauga Te'elagi (Photo by E.Edwards).

The method of sticky trapping for insects can sample a range of walking or sometimes flying insects by entanglement in sticky paste. A paper card with one sticky surface is stapled onto a tree surface or placed on the ground and is particularly good for detecting colonies of invasive ants. The method in this survey involved placing cards at 40 -60 metre intervals along an altitudinal sequence associated with the access from A'opo –Asau highway to ~1200 m asl. on the Mata o le Afi access track. Because ants might be expected to invade along tracks in the first instance, a few sticky traps were placed in adjacent 'un-travelled' vegetation (Reported R. Fisher).

3. RESULTS

Moths and butterflies

The upland moth fauna proved relatively rich for the level of sampling effort. At the crater south of Mauga Te'elagi, weather hampered sweeping by day, but one night of calm, warm and overcast conditions was ideal for light trapping (see Figure 4.4). The expedition recorded ninety two species of moth in 20 families in this crater at 1370 m asl. (Table 4.1, Appendix 4.1). Nights were cooler at the Mata o le Afi camp 1560 m asl., and fewer species were recorded at night. Hand collecting of moths added a number of species at camp and in nearby habitats from ~900 metres to ~1850 metres at Mauga Silisili. Sixty eight moth species in 16 families are shown in Table 4.1 & Appendix 4.1. for this region. A low proportion of moth species were common to both sites –just 26 species and so the upland species count is 135 in 21 families including two butterfly species.

Of the 135 taxa recognised in the upland survey, 44 species or 33% have been identified with published species names but this includes the difficult and largely newly discovered micro-moth taxa. The majority (65%) of the large bodied macro-moths and butterflies are assigned to previously named species (see Appendix 4.1).

The biggest representation of species (including tag named species) by family was Crambidae with 28 species, followed by Tortricidae 19 species, Noctuidae with 18 species, Geometridae 14 species and Oecophoridae with 12 species (Table 4.1).

Butterfly results

Table 4.1 also shows a small number of butterfly families with only two butterfly species recorded and only one of those above 1100 metres. Big–eyed blue *Nacaduba dyopa dyopa* lives in forest with adults seen in glades and is native to islands of Fiji, Tonga and the Samoan islands. The other butterfly is the Samoan Ranger *Phalanta exulans* (Figure 4.5), which was common throughout during the expedition. This vivid orange species feeds on the small tree *Melicytus samoensis* which is scattered throughout forest and damaged forest areas (E. Edwards pers. obs., Whistler 1998). The Samoan Ranger is endemic to Upolu and Savai'i. Other butterflies can expect to be seen from time to time and this particularly includes Monarch *Danaus plexippus* and white butterflies in Family Peridae, which are known for wandering.

Figure 4.5. Samoan Ranger butterfly *Phalanta exulans*. The only butterfly breeding in the cloud forests above 1300 m. asl. Endemic to Upolu and Savai'I (Photo by E.Edwards).

Table 4.1. Moth fauna by family for two upland regions

	Localities			
Moth Family and common name	South crater Mauga Te'elagi	Mata o le Afi region	# spp. in both regions	Total # spp. regions combined
Noctuidae -Owlets & others	11	11	4	18
Nolidae -Tuft moths	5	1	0	6
Erebidae Subfam. Arctiinae -Tiger moths	2	1	1	2
Geometridae -Loopers or geometrid moths	11	8	5	14
Sphingidae -Sphinx moths	1	1	0	2
Crambidae -Crambid snout moths	18	15	5	28
Pyralidae -Pyralid snout moths	4	1	1	4
Nymphalidae -Brushfooted butterflies	1	1	1	1
Lycaenidae -Blue butterflies		1		1
Thyrididae -Window winged moths	1			1
Tortricidae -Leaf rollers and bell moths	12	9	2	19
Immidae -Immid moths	1			1
Epermeniidae -A micro-moth family		2		2
Carposinidae -Fruitworm moths	2	2	0	4
Gelechiidae -Twirler moths	4			4
Stathmopodidae -Bristle legged micro-moths	3			3
Elachistidae -Grass or sedge miner moths		2		2
Oecophoridae -Concealer moths	7	7	2	12
Plutellidae -Diamond-backed moths	1			1
Gracillariidae -Leaf miner moths	6	2	2	6
Tineidae -Clothes moths	2	4	2	4
Total number of species	**92**	**68**	**25**	**135**

Another butterfly *Hypolimnas errebunda* Samoan eggfly is a species endemic to Upolu and Savai'i. It has been recorded with larvae feeding on *Cypholophus macrocephalus* (Urticaceae, Swezey 1942). This large leaved shrub is noted as growing up to 1150 m asl. in Fiji (Heads 2006) and up to 1120 m asl. in Samoa (Whistler 1998). Despite Samoan eggfly being seen in Savai'i in 2010 (E. Edwards unpublished) and noted on the A'opo flow at low elevations, it was not seen during the expedition in the uplands or in suitable lower altitude vegetation. Thus it remains possible that this butterfly may be seen at or above 1100 m when seasonally abundant. The lack of occurrence for two other butterflies, Upland jezebel and pepe ae Samoan swallowtail, are also noted here. Many species of jezebel butterfly genus *Delias* (Peridae) have larvae on *Amyema* spp. mistletoes, live at high altitudes and disperse widely (see Parsons 1999 for New Guinea region). On Savai'i the parasitic mistletoe plant *Amyema artensis* is occasional and widespread at high elevations on Savai'i (Whistler 1978), and this genus is also widespread in island forests west to Papua New Guinea and Australia and yet no *Delias* species butterflies were recorded. Lastly, during the expedition, no examples of pepe ae were seen (See figure 4.9 below; endangered Samoan swallowtail butterfly *Papilio godeffroyi*). Pepe ae is endemic to Samoa and American Samoa and now remains as a relict population on Tutuila Island since it is apparently gone from the rest of the archipelago. Hence recent surveys have concluded local extinction on Savai'i (Conservation International *et al*. 2010, Edwards 2008, Edwards 2010). The BIORAP survey unfortunately supports the conclusion with none seen. Talafalu (*Micromelum minutum)* is the host plant for pepe ae caterpillars. This tree grows in forest and successional forest to about 300 m asl. The same plant family (Rutaceae) has two species of *Melicope* which can grow in cloud forest (Whistler 1978) and may have supported caterpillars of pepe ae in the past as some *Papilio* butterflies (sister species) in Papua New Guinea are known from both tree genera (Parsons 1999).

Figure 4.6. An elegant moth in the Family Carposinidae from Mata o le Afi. One of several new and unnamed discoveries (Photo by E. Edwards).

Upland moth endemicity

Endemicity is reported here (Table 4.2) for the three families Crambidae, Noctuidae and Geometridae. This is because each is represented by 14 or more taxa and also because a higher proportion of the larger moths are named and discussed in the literature (see Appendix 4.1.). Table 4.2 indicates about 30% endemicity for the moth fauna. This includes one genus, eight species and three sub-species. It is likely higher for the smaller moth families that could not be analysed here.

Only 2 out of 41 moths in Table 4.2 are considered exotic. These include breadfruit borer *Glyphodes caesalis* and an Australian leaf-flower moth *Hyalobathra unicolor*. The host plants for both these insects are not known in the uplands and thus these are essentially vagrant in the catch. The results show almost no pest or exotic Lepidoptera fauna influence above 900 metres. Table 4.2 and Appendix 4.1 also shows more than half the moths occur widely in the western Pacific region and are often species dispersed among Melanesia, Australia, Indonesia, and beyond.

Table 4.2. Endemicity for three species rich families (includes sub-species level)

	Crambidae	Noctuidae	Geometridae	Total for 3 Families
Samoan endemic	8	3	2	13 (32%)
Native to Samoa/Tonga/Fiji (& usually widely occurring)	11	8	7	26 (63%)
Introduced (& often widely occurring)	2	0	0	2 (5%)
Un-assigned distributional information limited or introduction uncertain	8	7	5	20
(sum by family)	**29**	**18**	**14**	**61**

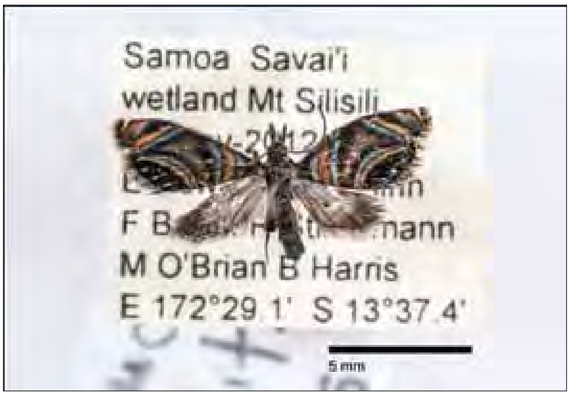
Percentages exclude the un-assigned species.

Habitat associations

Appendix 4.1 includes notes on what each species' caterpillars eat (where known) and on the range of localities where each species is found. Analysis of this information shows that among the assemblages of moths noted at Mata o le Afi and at the Mauga Te'elagi crater a range of habitats can be interpreted. Appendix 4.1 notes numerous 'tropical rainforest' associations among the list and some with an upland pattern of distribution from the survey and from the many historical records of taxa from 2,000 feet at Malololelei, Upolu, that were not reported at lower altitudes (Meyrick 1927, Hopkins 1927, Tams 1935). Upland examples include owlet *Anomocala hopkinsi*, *Tiracola rufimargo samoensis* and *Asura hopkinsi* (possibly with larvae on understory ferns).

Forest understory examples include ramie moth (*Arcte coerula* on shrubs in Urticaceae) and day active *Piletocera albescens* with larvae on forest floor herbs. Distinctive in the records is the vivid orange and black endemic lichen moth *Monosyntaxis samoensis* with larvae feeding on rainforest lichens or surface algae. Appendix 4.1 lists quite a few moths feeding on a range of trees, leaf mining, stem boring or feeding in flowers or fruits. A couple of moths are from grasses and some were recorded from wetlands or as wetland inhabitants. For example *Ambia schistochaeta* has larvae in ponded waters, *Glaucocharis dialitha* (Figure 4.7), *Oecophorid* gen sp. (3) & *Oecophorid* gen. sp. (4) are all recorded from damp sedgeland/wetland (see example habitat Figure 4.2).

Figure 4.7. Endemic moth *Glaucocharis dialitha* (Crambidae) one of a few moths found in upland wetlands (Photo by J.Rolfe).



When the records for Mauga Te'elagi and for Mauga Mata o le Afi are compared it is apparent that over two thirds of the fauna sampled is unique to each region (Table 4.1, Appendix 4.1). This result may show differences in habitats between the two sites (one is 270 metres higher in altitude) or that each sample is a small proportion of the total number of species present in each area. Probably both are true and the forests are not uniform but rather a vegetation mosaic at large landscape scales and many more species of moths remain to be discovered.

Table 4.3a. Moth families found in the survey with species notes

21 Families found in the expedition

Moth Family	Tag spp. per family	All upland records	Notes
Nymphalidae -Brushfooted butterflies	0	1	Samoan ranger butterfly the only summit dwelling butterfly -also endemic. Some of the other 11 species may possibly breed above 1100 m asl.
Lycaenidae -Blue butterflies	0	1	Only one lycaenid butterfly from 10 species breeding at high elevations. And none near the summit region
Thyrididae -Window winged moths	0	1	Samoan endemic species recorded and others likely
Immidae -Immid moths	1	1	One tag species noted. Tams (1935) records two species with one endemic.
Plutellidae -Diamond-backed moths	1	1	New family record and new species as no Plutellid moths are published from Samoa
Erebidae Subfam. Arctiinae -Tiger moths	0	2	Both endemic forest and upland species and more species to be documented.
Sphingidae -Sphinx moths	0	2	Two widespread species. Sphinx moths are strong fliers & can disperse widely
Epermeniidae -A micro-moth family	2	2	Likely both new species. None in this Family have been described from Samoa
Elachistidae -Grass or sedge miner moths	2	2	Probably both new species. No moths in this family have been described from Samoa
Stathmopodidae -Bristle legged micro-moths	3	3	Probably all new species though Meyrick (1927) also notes three species.
Pyralidae -Pyralid snout moths	0	4	All named and all cosmopolitan widespread species
Carposinidae -Fruitworm moths	4	4	Likely four new species. Meyrick (1927) notes two species with one endemic
Gelechiidae -Twirler moths	4	4	All four from one locality indicating there are many more native species to be found in the uplands. Meyrick (1927) notes 16 species among Samoan Islands of which 12 were only known from Upolu
Tineidae -Clothes moths	4	4	Likely native new species. Meyrick (1927) records 27 species with many being native
Nolidae -Tuft moths	6	6	Family poorly documented here. Robinson (1975) notes 5 for Fiji islands. Expect named and new species.
Gracillariidae -Leaf miner moths	6	6	Likely all new species. Meyrick (1927) records 8 species with 5 endemic
Oecophoridae -Concealer moths	12	12	Some will prove to be named species and one or two exotic species are possible. Likely most are new species. Meyrick (1927) and Comstock (1966) note 11 species with 6 endemic
Geometridae -Loopers or geometrid moths	5	14	Group well documented with many forest species but still expect to discover a few upland shrub inhabiting species.
Noctuidae -Owlets & others	7	18	Group well documented. However, some new species of *Schrankia* discovered in the survey. The large upland subspecies *Tiracola rufimago samoensis* was abundant. And, found an endemic owlet genus *Anomocala hopkinsi* not seen since 1920's.

Moth Family	Tag spp. per family	All upland records	Notes
Tortricidae -Leaf rollers and bell moths	19	19	None are named but should be able to work through reference material for many. Meyrick (1927) notes 21 species with 10 being endemic. Likely that only a small number of native upland species have been surveyed.
Crambidae -Crambid snout moths	11	28	A species rich family with many regional and local endemics. In part, the un-named component represents an upland fauna.
21 families recorded in uplands	**87**	**135**	

Table 4.3a summarises the number of higher altitude moth species by family which are contrasted in note form with the fauna known from the Samoan islands in the same table and also in Table 4.3b. Table 4.3b includes the 16 families not represented in expedition samples. Whilst some of these include species that will be found at higher altitudes in future, the overall result shows a simplified assemblage in uplands.

The total number of tag named species shown in Table 4.3a is 87. A number of comparisons with published taxonomic information are made in the same table and in Appendix 4.1 showing almost no moth sampling above '2000 feet' (~600 metres asl.) prior to this expedition (See also Hopkins 1927, Meyrick 1927, Prout 1928, Tams 1935 and Comstock 1966). Also shown in Table 4.3a, is the dominance of tag named species among Families of small moths (eg. Tortricidae, Oecophoridae and Gracillariidae). Among these micro-moth families, published information for Samoan Islands shows endemism around 60% (Meyrick 1927, Comstock 1966). This is in addition to 30% endemism for the published species among Crambidae, Noctuidae and Geometridae in Table 4.2. In these three better known families any species difficult to determine are unlikely to be widespread. The tentative analysis is that more than half of the 87 tag named species have never been collected previously and are new to science.

Table 4.3b. Moth families documented in Samoa but not found in the survey

Moth family and common name	Notes
Erebidae Subfam. Lymantriinae* -Tussock moths	Larva newly recorded in forest ~850 m asl. likely cryptic native related to Fijian spp. but may be exotic –adult needed to verify
Uraniidae -Swallowtail moths	Tams (1935) records six species, some easily found -not an upland family
Peridae -White butterflies	Four species, one locally extinct. Not upland butterflies
Hesperidae -Skipper butterflies	Two Samoan species. Not upland butterflies
Papilionidae -Swallowtail butterflies	Pepe ae Samoan swallowtail. Locally extinct
Lacturidae -Tropical burnet moths	Meyrick (1927) records one species
Choreutidae -Metalmark moths	Meyrick (1927) records two species with one being native
Pterophoridae -Plume moths	Meyrick (1927) records two exotic species
Alucitidae -Many plumed moths	Meyrick (1927) records one species
Cosmopterygidae -Cosmet moths	Meyrick (1927) records 28 species with about half endemic
Coleophoridae -Casebearer moths	Meyrick (1927) notes one species from coconut. Not expected in uplands
Batrachedridae -A micro-moth family	Meyrick (1927) records one species
Blastobasidae -A micro-moth family	Meyrick (1927) notes two exotic species and not expected in uplands
Heliodinidae -A micro-moth family	Meyrick (1927) records one species

Moth family and common name	Notes
Yponomeutidae -Ermine moths	Meyrick (1927) records four species
Psychidae -Bag moths	Tams (1935) records two species. Can be cryptic and may be in uplands.
Hepialidae -Ghost moths	One species native to Fiji and Samoa (Tams 1935). Probably a seasonal flight period. Potentially in uplands
16 families plus a sub-family. (* Subfamily Lymantriinae has been included based on a caterpillar instar and regional context for the group. onfidence will be increased by finding an adult or rearing caterpillars.)	

General non-forest habitat observations

Areas of open non-forest habitat are few, small in extent and highly distinctive. Some habitats are minor in the landscape but are scattered across many places and some habitats are rare. Within forest expanses there are scattered small areas of impeded drainage with wetland soils and vegetation, or temporary ponds and flood channels. No aquatic insects were sampled during the biorap survey, but the aquatic fauna should provide insight about island relationships and endemism in the future. There are also very well drained volcanic rubble and cinder areas where forest is restricted, and a few sites where cold air ponds on still nights severely limited the vegetation cover. While areas of heath-like open forest and shrubland occur across the upper A'opo lava flow, the small areas of open, low vegetation around Mauga Mū and Mata o le Afi are very rare and extremely fragile natural areas.

Moths Mauga Mū track 200 -900 metres asl.

Noted in Appendix 4.1 are a few moths observed by day on this lower altitude access track. Exotic moths were an easily observed part of the fauna in contrast with uplands. Of note was a distinctive caterpillar from the Sub-family Lymantriinae (Family Erebidae, Figure 4.8) which is likely a new native but an adult is needed to verify.

Figure 4.8. Erebidae most probably subfamily *Lymantriinae* sp. moth caterpillar, ~800 m A'opo mill -Mauga Mu track. Likely native, possibly a pest (Photo by E.Edwards).

4. DISCUSSION

Moth and butterfly associations above 900 m asl on the extensive mountainous and volcanic landforms of Savai'i were surveyed for the first time during the BIORAP expedition. The composition of the Lepidoptera fauna reflects an extensive mosaic of native vegetation, including pockets of crater sedgeland/fernland, grassland, and shrublands among the rolling upland forest. The sampled fauna includes 135 species (87 of these tag named) in 21 families. The moth fauna includes a high proportion of species that are able to disperse far as adults, and where known plant associations are not present at the site but rather in the lowlands (eg. the crambid moths *Phostria oconnori* with larvae on jade vine (*Strongylodon*) and *Pharambara splendida* with larvae on lau pata (*Macaranga* spp.). There are very few known introduced species recorded and some of these are essentially lowland vagrants in an upland environment (e.g., breadfruit borer *Glyphodes caesalis*, and see Appendix 4.1). In common with many plant species in the Savai'i uplands (Whistler 1978, Whistler 1998), there are many moths with species ranges extending westward to Vanuatu, Papua New Guinea and beyond (eg. ramie moth *Arcte coerula* or Cacao Armyworm *Tiracola plagiata*), and a few are species also known in Australia. But also like the Savai'i flora (Whistler 1998) there are moth species shared only among the islands of Fiji, Tonga and Samoa (eg. geometrid *Cleora fowlesi* and crambid *Leucophotis pulchra*). About 30% of the larger named moths from Savai'i uplands are Samoan endemic (Table 4.2.), which is similar to analyses of regional distribution patterns given by Tams (1935) and Robinson (1975). But Munro (1996) calculates 13% endemism for Samoan butterfly superfamily Papilionoidea and 45% endemism for combined families Pyralidae and Crambidae. Lastly, 87 of the135 Lepidoptera (including two butterflies) recorded here are tag named entities reflecting a historical lack of upland survey and limited taxonomic resources for identifying the many micro-moths. However, a good proportion of the 87 un-named species will be expedition discoveries, new to science, and endemic to the upland habitats of Savai'i and possibly also to the uppermost forest and crater communities of Upolu.

In this study moths are a subset of the insect fauna. But their habitat associations show the diversity of faunal habitats occurring in a large rainforest area including a few non-forest habitats. Feeding damage in fruits, flowers, shoots, litter, epiphytes, lianes, heaths, sedgelands and shrublands are examples.

Butterflies are noticeably scarce above ~1100 metres asl. with only Samoan Ranger *P. exulans* and wandering Monarch *D. plexippus* being seen during periods of direct sun. This severe reduction in species richness is typical of tropical butterflies (Parsons 1999) and was expected here. While the Samoan Ranger (endemic to Upolu & Savai'i) is the only species actually breeding at altitude, it is not an upland specialist. Rather, on Savai'i, this butterfly is widespread among forest and disturbed forest occurring wherever its caterpillar host tree is established. The expedition also showed the presence of the mistletoe shrub *Amyema artensis* on branches of vivao *Reynoldsia pleiosperma* a widespread tree endemic across the Savai'i uplands. However, although this caterpillar host is suitable for jezebel butterflies (*Delias* species) that can specialise in uplands (Parsons 1999), none were seen. A species of *Delias* recently dispersed Australia to New Zealand (unpublished data) and some are present in Vanuatu (Tennent 2006).

Lastly, there were no observations of pepe ae (Samoan Swallowtail Butterfly *P. godeffroyi*; Figure 4.9) and extinction of this large majestic butterfly in Samoa is confirmed (while still extant on American Samoa). Prior to the survey, a limited potential existed for caterpillars to use an alternative upland host food tree (*Melicope* –plant family Rutaceae). Adults are known for flying far through forest stands making them easily detected even at low numbers by the many keen observers visiting many areas during the expedition. The observations validate the tentative proposed IUCN red list status of (EN) endangered.

Figure 4.9. Pepe ae, the Samoan Swallowtail Butterfly. Now extinct in Upolu and Savai'i, the last verifiable record is from Palauli 1979 (Photo by B. Rhode).

The moth Family Crambidae (snout moths) tops the list for species richness with 28 species sampled. Many of these are endemic among Fiji and Samoa (and likely Tonga for a few) as well as 8 species that are endemic to the Samoan islands (Table 4.2.). This represents a good example of the evolution or speciation of the fauna in a setting of oceanic isolation and long distance dispersal and also importantly, a reasonable expanse of habitats available among the three largest islands of Samoa (Robinson 1975, Holloway 1983, Holloway 1987, Munroe 1996). The Crambidae endemics sampled include species and subspecies but not genera (Appendix 4.1). This indicates, more limited time-spans associated with the volcanic origin of the islands (Quaternary 5.2 million years; Koppers *et al*. 2008) compared with the Fijian archipelago (plus 28 million years old; Neall and Trewick 2008) which has a higher proportion of endemic genera versus species (Robinson 1975). The exceptions with regard to level of endemism, includes, four Samoan genera of moths each with only one species in the Family Noctuidae. One of these *Anomocala hopkinsi* is evidently an upland specialist. Samoa is an outpost in the sense that eastward among Pacific islands beyond Samoa there are no locally endemic genera (Robinson 1975, Holloway 1983). The moth *Phassodes vitiensis* is in the primitive family of ghost moths Hepialidae. While not recorded for some time in Samoa (perhaps not since 1961 see Comstock 1966) or by the expedition it is of interest being the eastern most example of Hepialidae. This along with other moths and other insects such as cicada reach the edge of their range in the Pacific at Samoa, which may in part be due to the scale of such habitats as the Savai'i interior compared with the smaller rainforest or upland areas of eastward islands.

The timing of the sampling for this expedition being in May was towards the end of the wet season. The abundance of adult Lepidoptera is on average higher in these conditions although not for every species (Jansen 1973, Frith & Frith 1985, Morais *et al*. 1999, Arun & Vijayan 2004). Such seasonality of rainfall is best known for the A'opo –Asau region of the island which has the most pronounced dry season (Schuster *et al*. 1997) but the effect of increased altitude here is to provide a more continuous pattern of rainfall. This along with other effects from cooler temperature regime and reduced periods of direct sun can give rise to different faunal composition than in lowland settings. Contrasting the representation of moth families known from Samoa with those noted in uplands (Table 4.3a and 4.3b) shows that quite a number of moth families are not suited to upland conditions. Though some of the 16 families would have been overlooked in the sampling.

While some of the moths recorded above 900 metres asl. are thought of as pest species in some situations, they are most likely natives that happen to have dispersed widely and have an ability to feed on a range of plant species. *Tiracola plagiata* is native but known in other countries as cacao armyworm and can unfortunately do well on banana in some situations. Among the 136 species of moth recorded above 900 metres (Appendix 4.1) only 4 species may confidently be considered as exotic introductions (lesser rice leafroller *Cnaphalocrocis poeyalis*, breadfruit borer note above, *Hyalobathra unicolor* and painted meal moth *Pyralis pictalis*. None of these could be considered a pest species of upland ecosystems. A distinctive hairy caterpillar from the Sub-family Lymantriinae was found at ~850 metres asl. Lymantriinae is a new record for Samoan Islands but is native to Fiji with four species in two genera and some described by Robinson (1975) as rare forest species. This Savai'i forest record is probably native with the potential to have been introduced from Fiji or elsewhere. Given the worldwide problem with pest species in this family of moths it would be useful to confirm the species from adults.

Australian moths in the Sub-family Lymantriinae are some of the species identified as a threat to native forest systems for warm temperate vegetation (Newfield 2008). And while the Savai'i hinterland appears free of such pests, national border control remains important. There is also a very genuine risk from bio-control agents (often parasitic wasps) considered for crop pest insects that may attack native non-target moths or other insects. A number of species of micro-parasitic wasps, bugs and beetles are having such an impact in upland areas of Hawai'i (see Henneman & Memmott 2001, Sheppard *et al*. 2004 and Stilling 2004) and some may already be present in Savai'i.

Risk to natural values of invasive species in the context of landscape disturbance

A broader issue with biosecurity is shown by interpretation of vegetation sequences, snails and insect fauna associated with this survey. A range of factors can be expected to combine to threaten natural ecosystem qualities demonstrated by flora and fauna reporting from the expedition. The interior uplands of Savai'i are relatively free of exotic plants, insects and snails. Whistler (2012) discusses the vegetation response 20 years after the devastating effects of cyclones (in 1987, 1990 and 1991) and found that forest regeneration was strong and re-establishing composition and structure without competition from exotic plants. This situation might well be different in future if weeds and invertebrate pests get established where there are tracks or development (See Figures 4.10a&b & 4.11).

There is a historical absence of tracks above around 900 metres asl. penetrating the upland interior of Savai'i, and the shield volcanic landforms barely eroded by river catchment development and bounded by steep slopes also impede pest plant establishment. This large landscape scale buffering could change where two forms of disturbance come into play. Firstly, where tracking or development provides for entry and upland establishment of plant and insect invaders in very local or linear areas and, secondly, some form of wide-scale disturbance event that you might expect in any two hundred year period in Savai'i. Illustrating this point are a few studies. Raghubanshi and Tripathi (2009) working in upland Indian tropical forest recorded a combined impact of pest plants and forest disturbance on tree diversity. They recorded tree species loss and the sort of *lantana* thickets (*Lantana camara*) seen in the uplands of Upolu (920 -960 m asl. Mauga Le Pu'e Pers. Obs) in upland tropical forest areas. With (2002) and With (2004) model invasive spread in forest aided by disturbance. Laurence and Curran (2008) discuss the increased vulnerability of tropical forest to invasive plants when wind disturbance events are combined with the effects of forest fragmentation. In tropical forests, the synergistic effects of stochastic events like fire, cyclones and the presence of invasive species are reviewed by Wright (2005) who also includes the increased access for the hunting of keystone birds as part of a process altering the composition of forests. A recent hazard study for Savai'i (Cronin *et al*. 2006) analyses the obvious history of volcanic events and Appendix 4.2. reproduced from this analysis, maps potential volcanism in the following context "..throughout the Holocene, the youngest period in Earth's history, both big islands of Samoa, Upolu and Savai'i have been volcanically active with evidence for several active eruption centres within the last few thousand years. Though the available age data currently does not allow establishing reliable recurrence intervals for volcanic active periods, volcanism in Samoa is unlikely to have ceased .." (Cronin *et al*. 2006). It is likely that given enough time, any protected area in the uplands will eventually experience extensive landscape-scale ecological disturbance resulting from volcanic eruptions, or from cyclones and possibly from fire. This should be considered in determining the size of an area to be managed as well as prevention and management of pests.

Figure 4.10a. New track weeds including *Euphorbia reineckei* a lowland native not previously recorded at this altitude before. Mata o le Afi 1520m asl. May 2012 (Photo by E.Edwards).

Figure 4.10b. New upland weeds on the bulldozed track across scoria/rubble lavafield approaching Mauga Silisili 1640 m asl. Pushed up spoil on the right includes exotic grasses, annual herbs and lowland native tramp species *Euphorbia reineckei* (Photo by E.Edwards).

Figure 4.11. African snail *Achatina fulica* among a few pests already present in lowland areas that may spread higher up Savai'i rainforests aided where tracks exist (Photo by E.Edwards).

The expedition results combined with evidence-based studies referred to here suggest that the large area of habitat in the Savai'i hinterland is made more resilient to invasive organisms through its size, lack of upland pest sources and the habitat integrity that has been maintained (apart from one track). We have interpreted the invertebrate biota in the context of habitats and ecosystem processes, and Samoa's position in the Pacific. The nature of the future threats has been explored and we conclude the fauna and ecosystems are at a large landscape scale, have many unique dimensions and are of outstanding international significance. There are opportunities for the local communities on Savai'i to add these insights to their intergenerational understanding. The mantle of stewardship for these communities appears important in the process of realising their opportunities while at the same time conserving a very ancient and clearly dynamic wild upland heritage.

5. RECOMMENDATIONS

1) Build on existing work by additional surveys of insects and vegetation flowering/seeding at alternative times of the year and in other locations to extend and add significant value to knowledge gained by the expedition.
2) Important upland surface water streams were noted during the expedition but remain to be surveyed for likely unique fauna and riparian vegetation.
3) Investigate the complex of rat/mouse species present and their upland ecology.
4) Scope cat and pig ecology.
5) In this report invertebrates are discussed in terms of distribution, endemism, discoveries and habitat associations. Future work should build on this in order to name the species discoveries but, importantly, also begin to consider species under potential threat.

ACKNOWLEDGMENTS

The New Zealand Department of Conservation (DOC) supported the author's time for the survey organised and sponsored by the Secretariat of the Pacific Regional Environment Programme (SPREP) and the Ministry of Natural Resources and Environment (MNRE) through a grant from the Critical Ecosystem Partnership Fund (CEPF) administered by Conservation International. Warren Chinn added valuable expertise, comment, photographs and field support. I thank Bruce Jefferies, James Atherton, Suemalo Talie Foliga and So'oalo Tito Alatimu for organizing the trip logistics; Fred Brook, Elisala Ilaoa, Fialele Enoka, Robert Fisher, Suemalo Talie Foliga, Rebecca Harris, Mark O'Brian, Rebecca Stirnemann and Moeumu Uili for assistance with fieldwork; the New Zealand Defence Force for helicopter transport on Savai'i; the Samoan Ministry of Natural Resources and Environment for providing accommodation on Savai'i; John Dugdale for advice and encouragement in dealing with micro-moths; James Atherton for producing the locality map of collecting sites; and Fred Brook, John Dugdale, James Atherton and Greg Sherley for suggesting improvements to this report.

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Appendix 4.1. Records of moths and butterflies from Savai'i highlands and the A'opo Lava Flow

Most records from E. Edwards, W. Chinn, F. Brook, F. Enoka, R. Fisher, R. Harris, E. Ilaoa, M. O'Brian, R Stirnemann (Note: butterflies below 800 metres asl. A'opo larva flow are not reported here)

KEY TO LOCALITIES:

TC = Mauga Te'elagi south crater 1360 metres above sea level (asl.)

MA = Mauga Mata o le Afi region above 900 m asl. including wetlands and Silisili to 1860 m asl.

ALF = A'opo lava flow up to 800 m asl. Hand collecting only.

Taxon = often a named species but can also be undescribed or new species distinguished by the author but not classified beyond family or genus.

	Localities			
Taxon	**TC**	**MA**	**ALF**	**Notes**
Family Noctuidae -– Owlets & others				
Anomocala hopkinsi Tams 1935	1	1		A dark coloured owlet outwardly like NZ Meterana (Hadeninae), host unknown.Endemic to W Samoa (both main islands),Previously known from females from Malololelei 2,000 ', Upolu.
Achaea serva (Fabricius) 1775	1	1		Larvae arboreal on diverse shrubs and trees, e.g. *Ricinus*. Distributed India -Pacific occasionally adventive to NZ
Arcte coerula (Guenée 1852)	1			Ramie moth, larva on Urticacae (Robinson 1975), Fijian montane rainforest. Elsewhere distributed Asia -Pacific.
Athetis nonagrica (Moore 1884)	1			Larvae polyphagous, terrestrial. Distributed Asia -Pacific. Synonymous *Leucosmia nonagrica* (Walker 1863)
Chrysodeixis illuminata (G.S Robinson 1968)	1			Larva on weed herbs, common, widespead.. Distributed Melanesia and Polynesia. Widely distributed Samoan Islands.
Grammodes oculicola Walker 1858			1	Larva on *Phyllanthus* & *Glochidion* (Phyllanthaceae, Robinson 1975).Distributed Australia, Melanesia, Polynesia
Hydrillodes sp. (3)		1		Larvae in this genus known from dead leaves.
Hypena gonospilalis Walker 1866		1		Distributed Asia -Pacific
Hypena sp. (1)		1		Comstock (1966) lists two wide ranging species for American Samoa
Hypospila similis similis Tams 1935	1			Samoan endemic subspecies
Mocis trifasciata Stephens 1829			1	Larva on grasses (Poaceae). Distributed East Indonesia to Polynesia
Anigraea sp. (1)	1			A genus known in Australia and recorded in Fiji & Tutuila
Schrankia sp. (1)		1		Possibly the named Samoan endemic *Schrankia taona* (Tams 1935) previously recorded montane Upolu and Savai'i
Schrankia sp. (2)	1			Likely a new endemic species
Schrankia sp. (3)		1		
Schrankia sp. (4)		1		

Taxon	Localities TC	MA	ALF	Notes
Phlegetonia barbara Robinson 1975	1			Sister species feeds on Myrtaceae (Robinson 1975). Previously recorded Fiji main islands (Robinson 1975) and American Samoa (Comstock 1966, interpreted Robinson 1975). Robinson (1975) remark, "Extremelly rare; probably restricted to lowland primary forest".
Rivula dipterygosoma Tams 1935		1		Distributed Vanuatu, Fiji and Samoa. "An uncommon species most usually found in wet lowland localities" (Robinson 1975)
Tiracola plagiata (Walker 1857)	1	1		Cacao Armyworm. Larvae arboreal, polyphagous, e.g banana, yam, Citrus. Distributed Asia -Pacific and northern Australia
Tiracola rufimago samoensis Tams 1935	1	1		Upland Samoan endemic subspecies.
Family Nolidae -Tuft moths				**Larvae are litter feeders**
Nola sp. (1)	1			
Nola sp. (2)	1			Also recorded by author Savai'i A'opo 220 m asl. & Upolu -Mauga Le Pu'e 490 m asl.
Nola sp. (3)	1			
Nolidae gen. sp. unidentified (4)	1			
Nolidae gen. sp. unid. (5)	1			
Nolidae gen. sp. unid. (6)		1		
Family Erebidae Subfamily Lymantriinae -Tussock moths				
Lymantriinae gen. sp. unid. (1)			1	Recorded as a caterpillar only. A'opo Mill track ~850 m asl. New Sub-family record for Samoan Islands. But native to Fiji are four species in two genera and some described by Robinson (1975) as rare forest species. This Savai'i forest record is probably native but potentially introduced from Fiji or elsewhere. Given a worldwide problem with pest species among tussock moths, finding adults to confirm the sub-family and determine the species would be useful.
Family Erebidae Subfamily Arctiinae -Tiger moths				
Argina astraea (Drury 1773)			1	Larva on *Crotalaria* spp, Fabaceae which does not grow in uplands. Distribution Asia-Pacific.
Asura hopkinsi (Tams 1935)				Only swept Savai'i Mauga Elietoga 880 m. Previously known from montane Savai'i and Upolu (Tams 1935)
Asura pyropa Tams 1935	1	1		Larva possibly on montane ferns. Endemic to montane Savai'i and Upolu from 600 m asl. and above.
Monosyntaxis samoensis Rebel	1			Related spp. (in Lithosinae) feed on rainforest lichens (Common 1990). Endemic to Samoa.
Nyctemera sp. nr. *baulus* (Boisduval, 1832)			1	Larva on *Sonchus* and allies (Asteraceae). On Western samoa abundant at low to mid altitudes and seen on all visits 2008 -2012. Wings white, basally darkened.
Family Geometridae -Loopers or geometrid moths				
Geometridae gen. sp. unid (3)		1		Possibly genus *Eois* (Geometrinae)
Chloroclystis rubicunda Prout 1934	1	1		Larvae in this genus often in flowers. Robinson (1975); "an uncommon species of primary forest". Distributed Vanuatu to Samoa.

	Localities			
Taxon	**TC**	**MA**	**ALF**	**Notes**
Cleora fowlesi Robinson 1971			1	Larvae in this genus often in tall shrubland or trees. Known from Fiji and Samoa.
Cleora samoana Butler 1886	1	1		Species in this genus often have larvae in tall shrubland or trees. Recorded from unuoi *Eugenia reinwardtiana* or *Syzygium* family Myrtaceae. Distributed Samoa, Tonga and Fiji
Clepsimelia phryganeoides Warren 1897		1		Distributed Indonesia to Samoa and described in Robinson (1975) as "A rare species restricted to primary montane rainforest"
Gymnocelis sp. (1)	1			Some species feed in flowers of shrubs
Gymnocelis tylocera Prout 1930	1			Larvae have been found feeding on *Glochidion* species family Phyllanthaceae (Robinson 1975). Species known from Fiji. Newly recorded in this survey in Savai'i uplands
Mnesiloba eupitheciata (Walker) 1863	1			Larvae feeding in grasses including *Ischaemum indicum*. Distributed India -Pacific
Pyrrhorachis pyrrhogona (Walker 1866)	1	1		Common in forests. Distributed Asia -Pacific. Synonym *Comostola pyrrhogona*
Scotocyma miscix Prout 1934	1	1		Distributed Australia, Melanesia -Samoa. Known from Fiji & newly recorded in this survey in Savai'i uplands. Robinson (1975); "An uncommon species restricted to primary forest"
Scotocyma sp. (1) 'long palpi'	1			
Thalassodes charops Prout 1928	1			An emerald moth. Endemic to Samoan Islands. Larvae feed on at least Tavai *Rhus taitensis* Anacardiaceae. Also noted Asau 30m asl. before survey
Thalassodes sp. unid (1)	1			Emerald moths. Species in this genus have larvae feeding on a range of tree species
Thalassodes sp. unid (2)		1		
Ziridava dysorga Prout 1928	1	1		An abundant Samoan endemic species including American Samoa (Comstock 1966). It does not belong in genus *Ziridava* and may prove to be an endemic genus (Jeremy Holloway personal communication).
Family Uraniidae -Swallowtail moths				
Phazaca sp. (1)			1	Larvae in this genus known on Rubiaceae. Likely *P. kellersi* Tams 1935 -a Samoan endemic
Family Crambidae -Crambid snout moths				
Crambidae gen. sp. unidentified (1)		1		
Crambidae gen. sp. unid (3)				Only swept Savai'i Mauga Elietoga 880 m asl.
Crambidae gen. sp. unid (4)	1			
Crambidae gen. sp. unid (5)		1		
Agrioglypta eurytusalis (Walker) 1859	1			Moths in this genus have larvae on Moraceae including *Ficus*. Distributed Australia and Pacific. Also noted Asau 30 m asl. before survey
Ambia schistochaeta Tams 1935		1		Endemic to Samoan islands. Inhabits ponded waters. Type locality Pago Pago -new record for Savai'i. Recorded during an earlier visit by E. Edwards to Mata o le Afi 2008.

Taxon	Localities TC	MA	ALF	Notes
Aphrophantis sp. unidentified (1)	1			One distinctive species in this genus described by Meyrick from Fiji
Baeoptila ellipes Tams 1935		1		Endemic to Samoan Islands. Tams 1935 notes records from Upolu: Malololelei and Tutuila: Amauli
Bradina leptolopha Tams 1935		1	1	Endemic to Samoan uplands – noted in Tams 1935 '2000 feet' asl. and above.
Bradina parbattoides Tams 1935	1			Endemic to Samoan uplands
Bradina sp. (1) nr. *chloroscia*			1	Also noted Asau 30 m asl. before survey
Cnaphalocrocis poeyalis (Boisduval 1832)			1	Lesser rice leafroller. Larvae feed on rice and a range of grasses Poaceae. Distributed Africa, Asia and Pacific
Dracaenura adela Tams 1935	1	1		Endemic to Samoa
Exeristis sp. unid (1)	1	1		Tams (1935) notes four species; this upland series likely to include several species.
Glaucocharis dialitha (Tams 1935)		1		Endemic to Samoa. Survey records from wetlands below Silisili summit. Tams (1935) notes records from Upolu upland at Malololelei and Savai'i Fagamalo
Glaucocharis sp. (1)		1		Survey records from Mauga Silisili summit
Glaucocharis sp. (2)		1		Survey record from Mauga Silisili summit
Glaucocharis sp. (3)		1		Survey record from Maunga Mu larva/cinder field
Glyphodes caesalis Walker 1859	1			Breadfruit borer. Larvae known to feed on *Artocarpus* spp. breadfruit Moraceae. Distributed South East Asia to Australia and Polynesia
Herpetogramma rudis (Warren) 1892	1	1		Distributed South East Asia, Fiji and Samoa.
Hoploscopa astrapias nauticorum Tams 1935	1	1		Endemic to Samoa
Hyalobathra unicolor (Warren 1895)	1			Larvae in this genus known on Phyllanthaceae (leafflower/s) including exotic/tentatively exotic shrub/herb species in the Samoa's. Distributed Australia, Fiji and newly recorded Samoa
Leucophotis pulchra Butler 1886	1	1		Distribution -known Fiji and Samoa
Meroctena staintonii Lederer 1863	1			New record Samoa. Distribution known from New Guinea region (including highlands) and Fiji.
Palpita sp. (1)	1			Sp. nr. *P. spilogramma* (Meyrick 1934). Larvae in this genus known on Apocynaceae or Oleaceae
Phostria oconnori Tams 1935	1			Larvae recorded feeding on *Strongylodon* Fabaceae. Distribution known from Fiji and Samoa
Piletocera albescens Rebel 1915	1			Larvae on forest floor herbs, Adults fly low in sun-flecked areas. Distribution Samoa and Fiji
Piletocera ochrosema (Meyrick 1886)	1			Known from Vanuatu and Fiji -newly recorded Samoa
Piletocera xanthosoma Meyrick 1886			1	Endemic to Samoa. Larvae known from herbaceous monocots in Araceae family.
Stemorrhages oceanitis (Meyrick) 1886	1			Distributed among Pacific islands and descibed as upland for Rarotonga.
Sufetula hemiophthalma (Meyrick) 1884		1		Larvae in this genus known on Monocots. Distributed among Pacific Islands, Australia and Malaysia

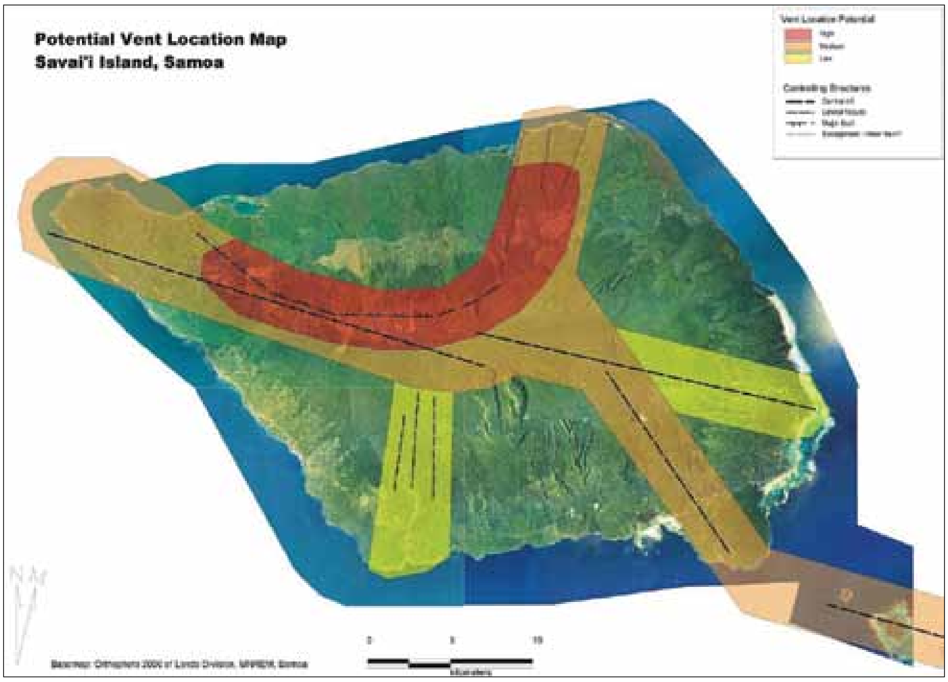
Taxon	Localities TC	MA	ALF	Notes
Syllepte sabinusalis (Walker 1859)	1			Larvae in this genus known on Urticaceae. Distributed Fiji to Papua New Guinea and Asia
Family Pyralidae -Pyralid snout moths				
Endotricha mesenterialis (Walker 1859)	1			Larvae feed on tropical trees including Calophyllaceae. Distributed South East Asia to Australia and Polynesia.
Pyralis pictalis (Curtis) 1834	1	1		Painted Meal Moth or Poplar Pyralis. Larvae eat dried vegetable foods e.g., cereals. Global distribution but likely native to Asia-Indonesia-Melanesia.
Thalamorrhyncha isoneura Meyrick 1933	1			Known elsewhere from Japan, Fiji and Australia.
Thalamorrhyncha zalorrhoa (Meyrick) 1934	1			Known in Fiji and likely elsewhere Melanesia
Family Nymphalidae -Brushfooted butterflies				
Phalanta exulans (Hopkins 1927)	1	1	1	Butterfly Samoan ranger. Endemic Upolu and Savai'i. Lavae feed on *Melicytus samoensis* a forest tree scattered throughout from remnant native forest at 350 m asl. to high elevations. Also note Tennant (2006) includes a confusing disjunct record of Palau for this butterfly -ignored in this assessment.
Family Lycaenidae -Blue butterflies				
Nacaduba dyopa dyopa Herrich-Schaeffer 1869		1		Butterfly, big-eyed blue. Adults seen in natural forest glades up to 1100 m asl. Distributed Fiji, Tonga and Samoan islands.
Family Thyrididae -Window winged moths				
Pharambara splendida Butler 1887			1	Larvae feed on *Macaranga* Euphorbiaceae. Distributed Australia, New Guinea/Melanesia and Polynesia. Synonym *Brixia dialitha* Tams (1935) from Samoa
Striglina oecia Tams 1935	1			Larvae recorded feeding on *Erythrina* Fabaceae. Endemic to Samoan Islands. Determined as *S. inversa* in Comstock (1966)
Family Tortricidae -Leaf rollers and bell moths				
Dudua sp. (1)	1	1		Some species in genus *Dudua* are polyphageous -where larvae eat a variety of plant species
Tortricidae gen. sp. unid (2)		1		Moths in this family known as leaf rollers
Tortricidae gen. sp. unid (3)		1		
Tortricidae gen. sp. unid (4)		1		
Tortricidae gen. sp. unid (5)	1			
Tortricidae gen. sp. unid (6)	1			Also recorded by author Savai'i Mauga Tagotala Quarry 260 m asl.
Tortricidae gen. sp. unid (7)	1			
Tortricidae gen. sp. unid (8)	1			Also recorded by author Savai'i Mauga Tagotala Quarry 260 m asl.
Tortricidae gen. sp. unid (9)	1			
Tortricidae gen. sp. unid (10)	1			Also recorded by author Upolu -Papapapaitai 675 m asl.
Tortricidae gen. sp. unid (11)	1			
Tortricidae gen. sp. unid (12)	1			

Taxon	Localities			Notes
	TC	MA	ALF	
Tortricidae gen. sp. unid (13)	1			
Tortricidae gen. sp. unid (14)	1	1		
Tortricidae gen. sp. unid (15)		1		
Tortricidae gen. sp. unid (16)		1		
Tortricidae gen. sp. unid (17)	1	1		
Tortricidae gen. sp. unid (18)		1		
Tortricidae gen. sp. unid (19)				Only swept Savai'i Mauga Elietoga 880 m asl.
Family Immidae -Immid moths				
Imma sp. (1)	1			Larvae in family Immidae feed exposed on foliage.
Family Sphingidae -Sphinx moths				
Agrius convolvuli (Linnaeus 1758)	1			Convolvulus hawk moth. Larvae feed on *Convolvulus* and *Ipomoea*. Global distribution.
Daphnis placida (Walker 1856)		1		Lesser marbled hawkmoth. Larvae feed on *Alstonia* Apocynaceae. Distributed Thailand to Australia and Polynesia.
Family Epermeniidae -A micro-moth family				
Epermeniidae gen. sp. unid (1)		1		Micro-moths. Larvae in family Epermeniidae mine leaves or feed in seeds, fruits and flowers
Epermeniidae gen. sp. unid (2)		1		Family not noted by Meyrick (1927) or Comstock (1966) (for American Samoa). The two examples here are probably both new species.
Family Carposinidae -Fruitworm moths				
Carposinidae gen. sp. unid (1)		1		A spectacular green and black species discovered on this expedition
Carposinidae gen. sp. unid (2)	1			Species in the Carposinidae family have larvae tunnelling in living bark, fruit or galls
Carposinidae gen. sp. unid (3)	1			
Carposinidae gen. sp. unid (4)		1		
Family Gelechiidae -Twirler moths				
Gelechiidae gen. sp. unid (1)	1			Micro-moths. Larvae in family Gelechiidae feed between joined leaves or mine inside stems and leaves
Gelechiidae gen. sp. unid (2)	1			
Gelechiidae gen. sp. unid (3)	1			
Gelechiidae gen. sp. unid (4)	1			
Family Stathmopodidae -bristle legged micro-moths				
Stathmopodidae gen. sp. unid (1)	1			
Stathmopoda sp. (5)	1			
Stathmopoda sp. (6)	1			Also recorded by author Savai'i Mauga Tagotala Quarry 260 m asl.

Taxon	Localities TC	MA	ALF	Notes
Family Elachistidae -Grass or sedge miner moths				
Elachistidae gen. sp. unidentified (1)		1		Micro-moths. Larvae in family Elachistidae are leaf or stem miners usually in grasses or sedges
Elachistidae gen. sp. unid (2)		1		
Family Oecophoridae -Concealer moths				
Oecophoridae gen. sp. unid (1)		1		
Oecophoridae gen. sp. unid (2)		1		Tentative *Vanicella* species. Also recorded by author Upolu -Mauga Le Pu'e 490 m asl. Genus *Vanicella* is sometimes placed in Roeslerstammiidae e.g. Neilson *et al*. (1996)
Oecophoridae gen. sp. unid (3)		1		Survey record wetland Mauga Silisili 1740 m asl.
Oecophoridae gen. sp. unid (4)	1	1		Tentative *Vanicella* species. Recorded from wetlands in three sites
Oecophoridae gen. sp. unid (7)	1	1		
Oecophoridae gen. sp. unid (15)		1		A large micro-moth family with a range of larval feeding strategies.
Oecophoridae gen. sp. unid (16)		1		
Oecophoridae gen. sp. unid (17)	1			
Oecophoridae gen. sp. unid (18)	1			
Oecophoridae gen. sp. unid (19)	1			
Oecophoridae gen. sp. unid (21)	1			
Oecophoridae gen. sp. unid (22)	1			
Oecophoridae gen. sp. unid (23)				Only swept Savai'i Mauga Elietoga 880 m asl.
Oecophoridae gen. sp. unid (24)				Only swept Savai'i Mauga Elietoga 880 m asl.
Family Plutellidae -Diamond-backed moths				
Plutellidae gen. sp. unid (1)	1			Family Plutellidae have some larvae in webbing on leaf surfaces.
Family Gracillariidae -Leaf miner moths				
Gracillariidae gen. sp. unidentified (1)	1	1		A micro-moth family. Gracillariid larvae mostly mine leaves
Gracillariidae gen. sp. unid (2)	1	1		
Gracillariidae gen. sp. unid (3)	1			
Gracillariidae gen. sp. unid (4)	1			
Gracillariidae gen. sp. unid (5)	1			Also recorded by author Upolu -Mauga Le Pu'e 490 m asl.
Gracillariidae gen. sp. unid (6)	1			
Family Tineidae -Clothes moths				
Tineidae gen. sp. unidentified (1)	1	1		Larvae in this family often feed on hard or dry fungal, animal or vegetable tissue.
Tineidae gen. sp. unid (2)		1		
Tineidae gen. sp. unid (3)		1		
Tineidae gen. sp. unid (4)	1	1		
Locality totals	**92**	**68**	**13**	

Appendix 4.2. Map of potential vent locations for Savai'i from Cronin *et al* (2006)

Copied with permission from Cronin, S., Bonte-Grapentin, M. & Nemeth, K. (2006). Samoa technical report – Review of volcanic hazard maps for Savai'i and Upolu. EU-SOPAC Project Report 59.



Appendix 4.3. Locality information of invertebrate survey sites

Locale	Elevation	Grid south	South Decimal Degrees	Grid east	East Decimal Degrees
Silisili small peaty crater	~1720 m	13°37.35′	-13.62242	172°29.33′	-172.48883
Silisili summit	~1880 m	13°37.12′	-13.61866	172°29.18′	-172.48633
Te'elagi camp and light trap	~1360 m	13°38.59′	-13.64316	172°24.72′	-172.41200
Mata o le Afi camp and light trap	~1640 m	13°36.62′	-13.61026	172°30.57′	-172.50943
Mata o le Afi Malaise trap	~1620 m	13°36.64′	-13.61066	172°30.33′	-172.50550
Silisili wetlands/forest	~1740 m	13°37.29′	-13.62150	172°29.21′	-172.48683
Cat scat Mauga Mū track	~1430 m	13°36.02′	-13.60033	172°31.33′	-172.52216
A'opo Mill – Mauga Mū track car park	~990m		-13.58726		-172.53294

CHAPTER 5

Report on the landsnail fauna of Upland Savai'i

FRED BROOK

1. INTRODUCTION

Savai'i is the largest and highest Samoan island (1718 km^2, 1870 m elevation), but previous knowledge of its landsnail fauna is poor compared to the other main islands in the group and, in particular, there is very little existing information on the fauna of the central range above c. 950 m. In May 2012 a multidisciplinary, reconnaissance ecological survey of the central range on Savai'i (i.e., the Tuasivi Ridge) was carried out to obtain information on the upland vegetation and fauna of this island. This survey was funded by the Critical Ecosystem Partnership Fund (CEPF), and was undertaken by the Secretariat for the Pacific Regional Environment Programme (SPREP), in partnership with the Ministry of Natural Resources and Environment (MNRE) and local communities on Savai'i. During this survey, the species composition and diversity of landsnail assemblages were determined at a series of forested sites on the Tuasivi Ridge, ranging from c. 990-1870 m in elevation. The present report describes the preliminary findings of this survey. Information on the landsnail fauna at lower elevations on Savai'i is given in Annex one to this report.

Previous work on the landsnail fauna of Savai'i

A brief account of previous work on Samoan landsnail faunas is given in an annex to this BIORAP report.. Historical landsnail collections from Savai'i include collections in the Bishop Museum, Honolulu, made by Edwin Bryan in 1924, Erling Christophersen in 1929 and 1931, and Tony Robinson in 1994; and the Field Museum of Natural History in Chicago contains a large collection made by Laurie Price in 1965. Almost all the material in these collections was obtained from sites at low to mid-elevations, with only three sites above 950 m elevation. The latter included a site at c. 1600-1700 m elevation above Safotu (1929), and two sites west and east of Mata o le Afi, at c. 1600 m and 1660 m, respectively (1994).

Descriptions and/or records of landsnail species from Savai'i are given by Mousson (1869), Garrett (1887), Baker (1938, 1941), Cooke (1942), Kondo (1943, 1968), Clench (1949), Girardi (1978), Solem (1983), Cowie (1998a) and Cowie & Robinson (2003). None of these publications make specific reference to landsnails from upland habitats on this island.

Aims of study

The main aims of the May 2012 snail survey were to obtain information on the composition, richness and biogeographic relationships of the landsnail fauna in the forested uplands above c. 950 m elevation on Savai'i, and to identify existing and potential threats to this fauna.

2. METHODS

In May 2012, eleven forested sites above 950 m elevation on Savai'i were surveyed for landsnails. These included nine sites along the upper part of the track between the A'opo sawmill and Mauga Silisili (c. 990-1870 m), and two sites at c. 1390 m and 1490 m elevation on an unnamed volcanic cone 1 km SE of Te'elagi (figure 5.1).

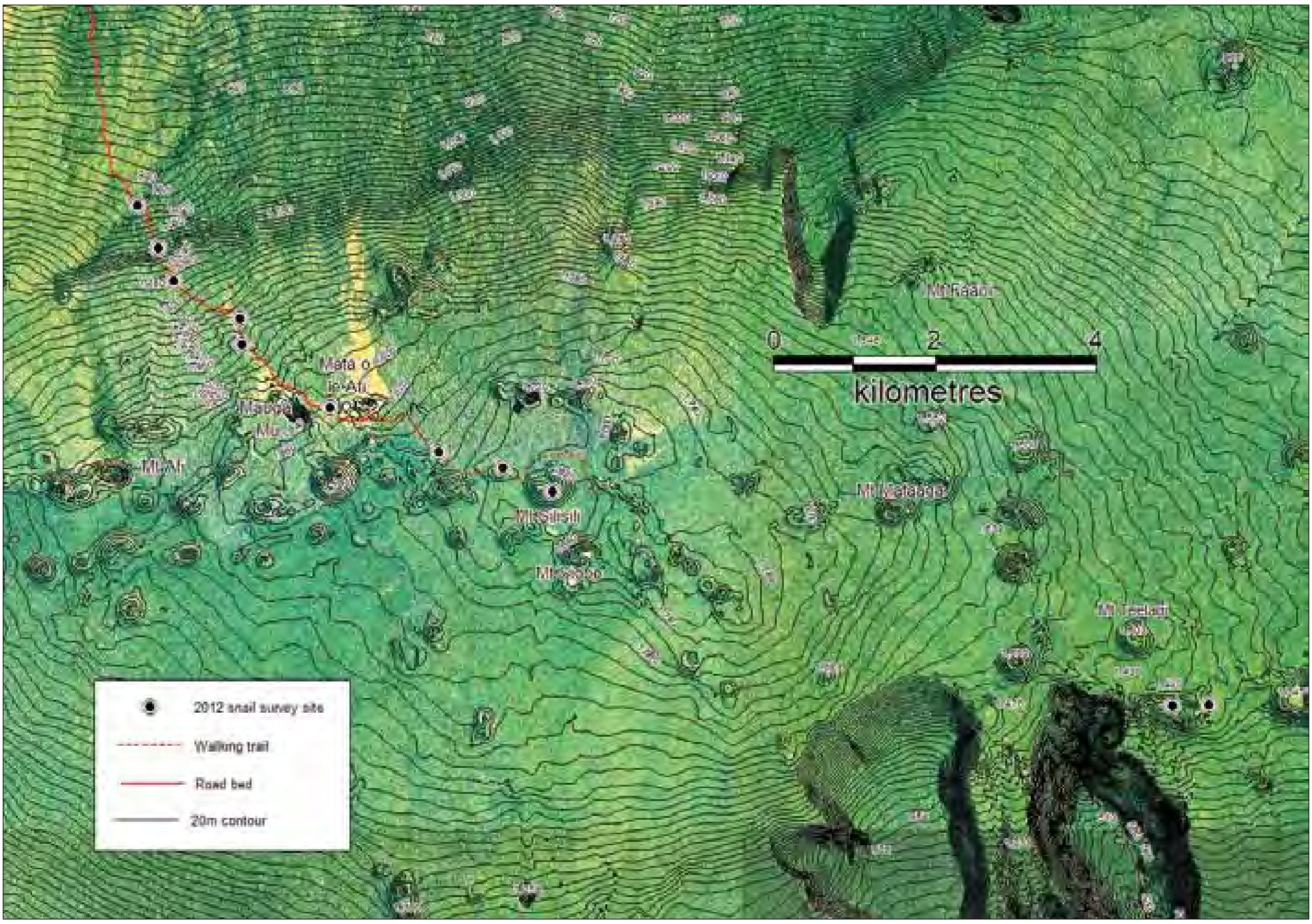
The geographic coordinates (WGS 1984) of sites were determined using a Garmin Etrex GPS unit. At each site the sampling protocol involved one person spending at least one hour searching for snails and empty shells by eye over an area of c. 100 m^2, and collecting a series of spot samples of leaf litter and humus with a combined volume of several litres, which were later dried and sorted under a binocular microscope for live snails and empty shells. The searches of sites by eye involved looking for snails and shells on the ground in leaf litter and under fallen wood and fern fronds, and on the leaves of ground-layer plants, shrubs, saplings and vines. This sampling regime was aimed at qualitatively covering as great a variety of microhabitats at each site as possible.

Empty snail shells found during the field survey were examined for evidence of predation. Empty shells with the outer lip bitten back, or with a hole bitten in the whorl periphery, were inferred to have been killed by rodents.

Identifications of the landsnail species found during this study were based on published literature where possible, but many of the species found are new to science and un-named, and are here identified to genus or family only. Information on the geographic distributions of named landsnail species was obtained from published literature, museum databases, and field observations made during the present study. Species were categorized as native or introduced on the basis of the available distributional and historical information.

Lists of landsnail species were compiled for each of the 11 survey sites, and from these the range and mean native species richness at sites, and frequency of native species at sites, were determined. A sample-based species accumulation curve with 95% confidence intervals using the Mao Tau analytical formula (Colwell *et al*. 2004), and estimates of total species richness using the Chao 2 (Chao 1987) and first-order Jackknife (Burnham & Overton 1979) richness estimators, were calculated for species incidence data from the 11 survey sites using EstimateS software (Colwell 2009).

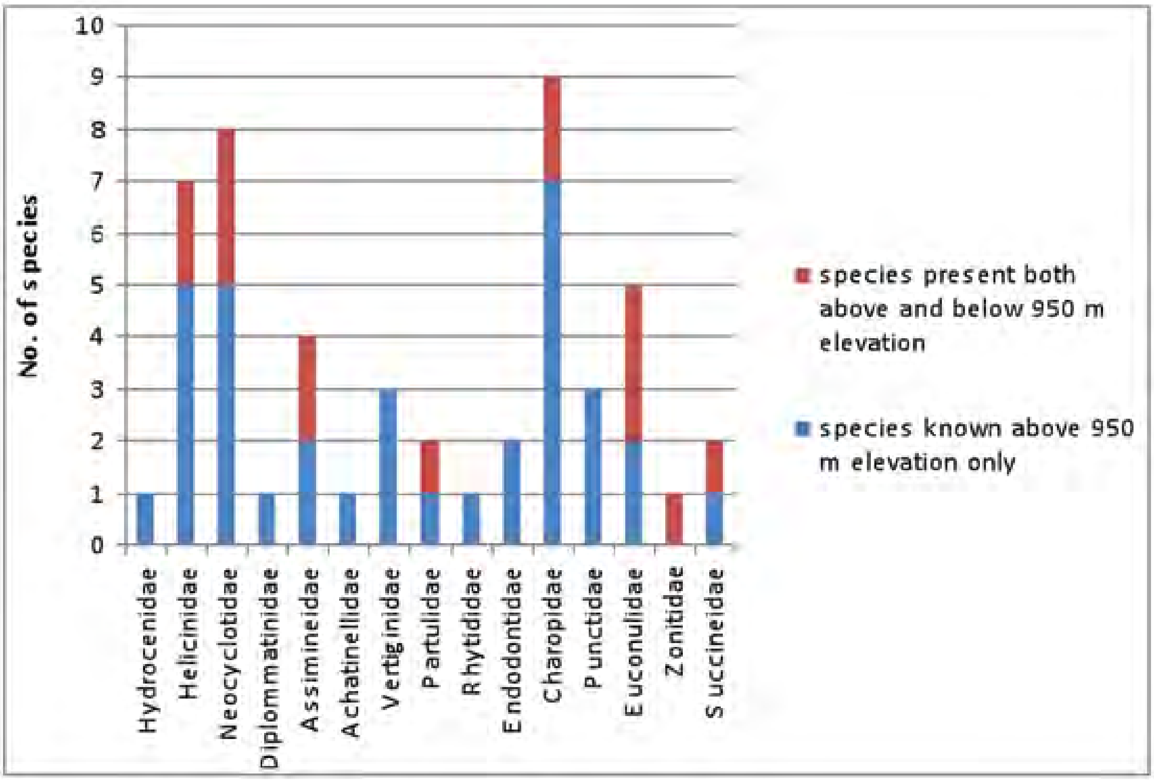
Figure 5.1. Location of sites above 950 m on Savai'i that were surveyed for landsnails in May 2012.



3. RESULTS

A total of 50 native landsnail species in 15 families, and one introduced species, are recorded here from the 11 sites above 950 m elevation on Savai'i that were surveyed in May 2012 (Appendix 5.1). The sole introduced species, *Bradybaena similaris*, was present up to c. 990 m elevation; the landsnail assemblages at sites at higher elevations contained native species only. The richness of native landsnail assemblages at the 11 sites ranged from 17-22 species per site, with a mean of 18.64 + 1.57 SD. Of the 50 native species, 14 species in eight families are named and have been recorded previously from lowland and/or foothill forest habitats on Savai'i; ten of these 14 species are endemic to Samoa. The other 36 native species, comprising 72% of the upland landsnail fauna, are unnamed, and have not been recorded previously from Savai'i or elsewhere. They include seven species of Charopidae, six species of Helicinidae, five species of Neocyclotidae, three species each of Punctidae and Vertiginidae, two species each of Assimineidae and Endodontidae, and one species each of Achatinellidae, Diplommatinidae, Hydrocenidae and Rhytididae (figure 5.2, Appendix 5.1). One of the unnamed species, *Sturanya* sp. 1, was also found at a site at c. 880 m elevation above Asau during the present survey (Brook 2012), but the other 35 unnamed species were found above 950 m only. All of these unnamed species are probably Samoan endemics, and it is likely that many, if not all, are restricted to the uplands of Savai'i.

Figure 5.2. Taxonomic composition of the upland (>950 m elevation) native landsnail fauna on Savai'i.



Most of the unnamed native landsnail species found above 950 m belong in genera that are also represented in the fauna at low to mid elevations on Savai'i, and all of these genera except the endemic Samoan *Ostodes* (Family Neocyclotidae), are widely distributed among other tropical South Pacific islands. However, the upland landsnail fauna on Savai'i also includes unnamed and presumably endemic species in the family Punctidae, which in shell morphology appear to be most closely related to subtropical and temperate taxa from the East Australian-New Zealand region. There are no previous records of native punctid snails from west Polynesia, and the only known records in southeastern Polynesia are an unnamed species from forest at 1700-1900 m elevation on Tahiti, and *Punctum polynesicum* from lowland habitats on Raivavae and Tubuai islands in the Austral group (Solem 1983). Some of the unnamed species of Charopidae discovered during the May 2012 survey also belong in genera not previously recorded from Polynesia, but the systematics and biogeographic relationships of these taxa have not yet been determined.

A histogram plot of native landsnail species frequency at the upland sites surveyed on Savai'i in May 2012 is shown in figure 5.3. The group of species with altitudinal distributions extending above and below 950 m elevation (i.e., all the named species in Appendix 5.1, and *Sturanya* sp. 1), showed a wide range of frequencies at upland sites, ranging from rare species found at one or two sites only, to species present at many or all the upland sites. The most widely distributed species in this group included *Diastole schmeltziana* var. *usurpata*, *Lamprocystis perpolita*, *Ostodes garretti*, *Succinea putamen* and *Trochomorpha troilus* var. *savaii*. Previously known species that were rare or sparse at upland sites included *Samoana canalis*, which was present up to c. 990 m elevation but was not found at any sites at higher elevations, *Discocharopa aperta*, *Omphalotropis biliratus*, *Omphalotropis conoideus* and *Sinployea allecta*. Several of the unnamed upland-restricted species were widely distributed among the survey sites, but a large majority had much narrower distributions, with 20 species (57%) found at one or two sites only (figure 3).

A sample-based species accumulation (Mao Tau) curve for the 11 upland sites surveyed on Savai'i in May 2012 is shown in figure 5.4. This curve is clearly non-asymptotic, indicating that the true total native landsnail species richness in the areas sampled above 950 m on Savai'i is higher than the total of 50 species recorded during the present survey. Estimations of total landsnail species richness (mean and standard deviation) determined by the Chao 2 and first-order Jackknife algorithms, using species incidence data from the 11 upland sites, were 59.8+6.8 and 62.7+3.0 species, respectively. However, the fact that only a very small part of central Savai'i was sampled during the present survey indicates that the actual species richness of the upland habitats on this island is probably considerably higher than these estimated totals.

Most of the empty snail shells found at the 11 upland sites on Savai'i were intact, but a small proportion of empty *Ostodes* and *Sturanya* shells showed damage typical of rodent predation, with the outer lip bitten back, or a hole bitten in the shell periphery. Shells with these types of damage were present throughout the elevation range sampled (i.e., c. 990-1870 m), and were found scattered in and on leaf litter on the forest floor, and as caches under ledges and in rock crevices.

Figure 5.3. Native landsnail species frequency at the 11 upland sites (> 950 m elevation) surveyed on Savai'i in May 2012.

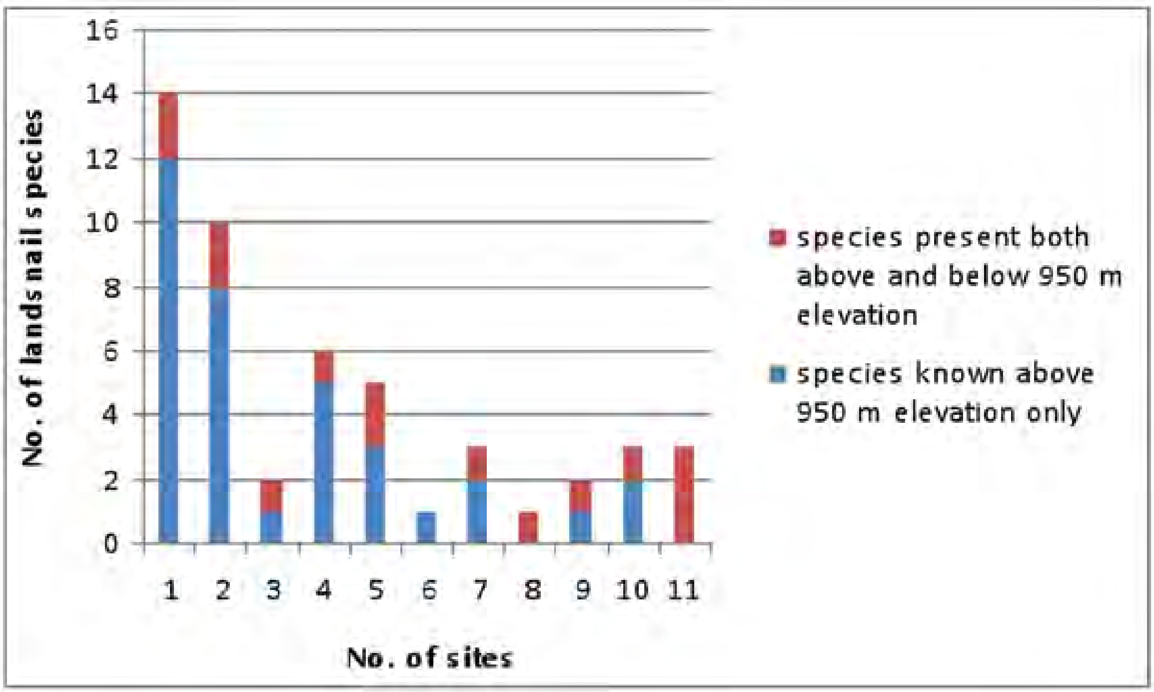
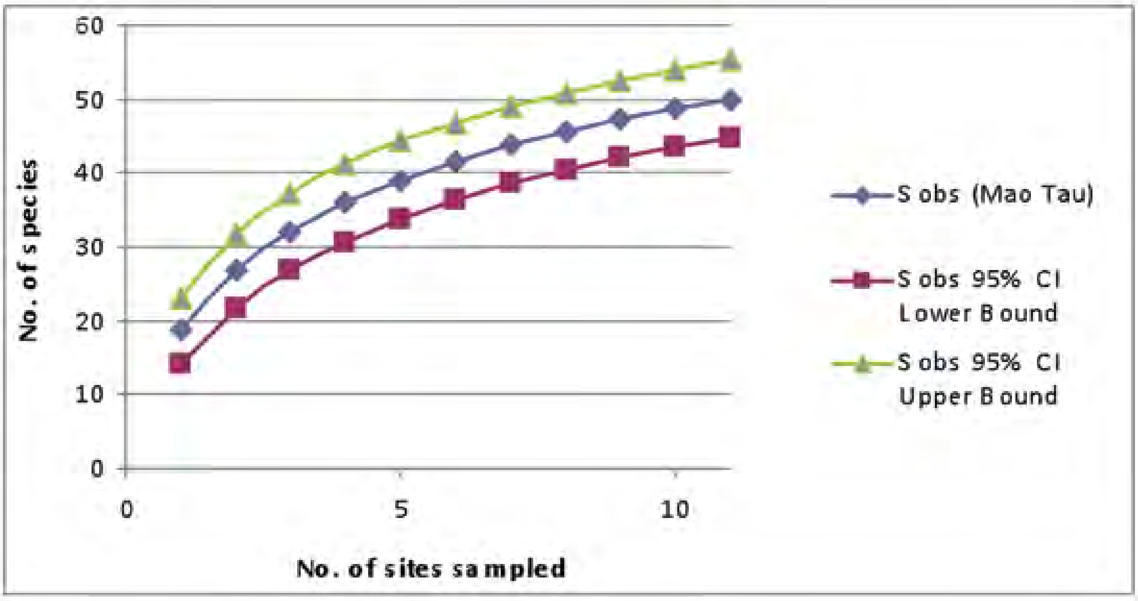


Figure 5.4. Sample-based species accumulation (Mao Tau) curve, and 95% confidence intervals, of landsnail species incidence at the 11 upland sites (> 950 m elevation) surveyed on Savai'i in May 2012.



4. DISCUSSION

The landsnail faunas of tropical Pacific islands have been particularly vulnerable to ecological changes following human settlement. Synanthropic faunal changes on Polynesian islands have typically included the inadvertent or intentional introductions of alien (i.e., non-indigenous) landsnails and slugs, and declines and extinctions of endemic and indigenous landsnail species (e.g., Cowie 2001a), which have generally been attributed to habitat modification and destruction, and/or predation by non-indigenous vertebrates and invertebrates. Some alien landsnail species were introduced to Polynesia prior to European contact (e.g., Christensen & Kirch 1981; Preece 1998), but the majority have evidently been introduced since the mid to late 1800s (e.g., Solem 1964; Solem 1983: 311; Cowie 1998b, 2001a; Brook 2010). The patterns of faunal changes in American Samoa, Upolu and in the lowlands and foothills of Savai'i are typical of islands throughout Polynesia, with declines and possible extinctions of native landsnail species, and the establishment of many alien species (e.g., Miller 1993; Cowie 2001b; Cowie & Rundell 2002; Cowie *et al*. 2002; Cowie & Robinson 2003; Brook 2012). By contrast, the central highlands of Savai'i still have a rich and taxonomically diverse native landsnail fauna, with no alien species known above 1,000 m elevation. Fifty native landsnail species were found in the upland areas surveyed in May 2012, but Chao 2 and first-order jackknife estimations indicate that the actual total native species richness in the areas sampled is probably c. 20% higher than presently known, and the total number of landsnails present across the entire central uplands is probably considerably higher still. Most of the landsnail species in the upland fauna have not been recorded previously from Savai'i or elsewhere, and it is likely that many or all of these are endemic to the Savai'i uplands. The generic composition of the upland fauna on Savai'i is of particular biogeographic interest, in containing at least eight species of the endemic Samoan genus *Ostodes*, along with widely distributed tropical genera, charopid genera not previously recorded from Polynesia, and punctid genera with subtropical-temperate affinities.

The persistence of a diverse, native landsnail fauna in upland habitats on Savai'i contrasts markedly with the severely depleted native landsnail fauna at lower elevations on this island, and on most other Polynesian islands. Comparable relict native-dominated landsnail faunas have also been reported recently from upland habitats on a few other high Polynesian islands, including Tahiti in the Society Islands (e.g., Coote & Loeve 2003; Gargominy 2008) and the Hawaiian islands of Hawai'i and Maui (Cowie *et al*. 1995; Severns 2011). The survival of these faunas has been linked to the persistence of native shrubland and forest vegetation in the central uplands of each of these islands, and to an absence or scarcity of key alien predators in the respective upland habitats.

Threats

Evidence from other tropical Pacific islands, and the history of environmental changes in low to mid elevation habitats on Savai'i, indicate that the landsnail fauna in the central part of this island is at risk from a wide range of threats, including in particular: habitat loss and modification from logging, land development, fires, storm damage, livestock, and weed invasion; and predation by introduced species (e.g., including flatworms, predatory snails, ants, rodents, pigs). Endemic landsnail species with highly restricted or sparse distributions would be particularly susceptible to such threats.

Rats are present on the Tuasivi Ridge and evidently prey on several species of ground-dwelling and semi-arboreal landsnails in the genera *Ostodes* and *Sturanya*, as indicated by characteristic patterns of shell damage, and caches of shells. Pigs are also present throughout the uplands of Savai'i, and while no direct evidence of pig predation of snails was found during the present survey, it is likely that they are opportunistic predators of the larger species of *Ostodes* and *Succinea*.

Many species of non-native tropical ants have become established at low to mid elevations on Savai'i (Wilson & Taylor 1967; Wetterer & Vargo 2003), but none appear to have spread into the upland habitats on this island as yet. Among these are the highly invasive predatory species *Anoplolepis gracilipes* (Crazy ant), *Paratrechina longicornis* and *Pheidole megacephala* (Big-headed ant), which have been implicated in declines and extinctions of native invertebrates on other tropical islands. It is not known at present whether the existing upper altitudinal ranges of these and other introduced ant species on Savai'i represent active invasion fronts that are moving up the island, or climatically-determined limits. Whichever the case, altitudinal shifts in the distributions of these species related to climate change (below) or other causes, would clearly pose serious threats to the upland landsnails and other native invertebrates on this island.

Samoan Ministry of Agriculture and Fisheries records indicate that the snail-eating flatworm *Platydemus manokwari* was introduced to Savai'i between 1996 and 1998, in an attempt to control the Giant African Landsnail (*Achatina fulica*), which itself had been accidentally introduced to this island in 1996 (Juvita Tone pers. comm. 2012). Further introductions of *P. manokwari* were carried out in 2001 by the Ministry of Agriculture and Fisheries to many villages around Savai'i (Juvita Tone pers. comm. 2012). The introduction and spread of this flatworm species on other tropical Pacific islands has resulted in declines and extinctions of native arboreal and ground-dwelling landsnail species (e.g., Hopper & Smith 1992; Sugiura *et al*. 2006; Ohbayashi *et al*. 2007; Sugiura *et al*. 2009; Iwai *et al*. 2010), and it poses a serious threat to the native landsnail fauna of Savai'i. No individuals of *P. manokwari* were seen at any of the sites surveyed during the present study, and the current distribution of this species on Savai'i is not known. Over time it will probably become widely distributed at low to mid elevations on Savai'i, but whether it will be capable of invading the cooler uplands is unknown.

Also of particular concern is the risk that the snail *Euglandina rosea* will be intentionally or accidentally introduced to Savai'i from other Samoan islands or elsewhere. This predatory species is notorious for having caused the decline and extinction of numerous native snail species on tropical Pacific islands (e.g., Hadfield 1986; Murray *et al*. 1988; Griffiths *et al*. 1993; Hadfield *et al*. 1993; Cowie & Cook 2001; Coote & Loeve 2003; Meyer & Cowie 2010a), and would undoubtedly do the same on Savai'i. There are also many other 'alien' predatory invertebrate species that have become established elsewhere in the Pacific region, and which could pose a serious threat to native landsnail species on Savai'i should they become established on this island. This includes: tropical species, such as the fire ants *Solenopsis geminata* and *Wasmannia auropunctata*, snails in the family Streptaxiidae, and temperate species of ants (e.g., the Argentine ant *Linepithema humile*), landsnails (e.g., *Deroceras laeve*, *Oxychilus* spp.), and malacophagous flatworms in families Bipaliidae, Geoplanidae and Rhynchodemidae (see Winsor *et al*. 2004). Invasions by temperate and subtropical predatory species would be of particular concern in the cooler upland habitats on Savai'i (cf. Meyer & Cowie 2010b).

Populations of upland landsnails on Savai'i are also potentially at risk from transmission of pathogens from introduced landsnails and slugs. As with introduced ants, it is not known if the existing upper altitudinal limits of tropical alien landsnails on Savai'i are climatically limited, or represent active invasion fronts, but in either case it would still be possible for pathogens to be secondarily transmitted by native landsnail species with altitudinal ranges extending up into upland habitats. Although only speculative, it is possible that climate warming could alter the dynamics of molluscan diseases in upland habitats on Savai'i, leading to an increased risk of pathogen outbreaks in populations of upland landsnail species (cf., Pounds *et al*. 2006).

Habitat destruction and modification resulting from logging and land development have undoubtedly been a major cause of declines of native landsnail species in the lowlands and foothills on Savai'i, and are a potential threat to the upland habitats on this island. Invasive alien weeds, particularly smothering vines, also pose a potential threat to the forests and shrublands in these upland habitats. The vehicle track between the A'opo sawmill and Mauga Mata o le Afi presently provides an access route for the spread of invasive, non-native plants and invertebrates (including ants and snails) into the upland habitats on Savai'i. In particular, vehicle traffic on the upper part of the track (i.e., above c. 1,000 m elevation) will contribute significantly to the spread of invasive weeds and invertebrates into this area.

Climate change poses several different kinds of threat to the native upland biota on Savai'i. A warming climate will enable invasive alien tropical plant and animal species to spread to higher altitudes, and climate-forced altitudinal shifts in distributions of native plant and animal species could potentially lead to narrower distributions and possibly the disappearance of endemic high altitude species and ecosystems from this island. Chen *et al*. (2009, 2011) reported climate-related altitudinal shifts in the distributions of montane moth assemblages over the last several decades on Borneo in the western tropical Pacific, and it is likely that the distributions of upland snails and other invertebrates on Savai'i have undergone similar shifts. Island tropical upland cloud forests are also particularly susceptible to climate-driven shifts in patterns of atmospheric circulation (Loope & Giumbelluca 1998). On Savai'i, as on other high tropical islands, there is a risk that atmospheric changes associated with warming and increased carbon dioxide concentration could lead to reduced cloud contact and increased evapo-transpiration (see Still *et al*. 1999), with consequent adverse impacts on the cloud forest ecosystems and the endemic plant and animal species that inhabit them.

5. CONCLUSIONS

The uplands of central Savai'i are extremely important in terms of landsnail biodiversity and conservation. Over the last hundred years or so, the landsnail faunas of all but a very few tropical Pacific Islands have suffered massive extinctions of native and endemic species, and invasions by non-native, 'alien' snail and slug species from Africa, Asia and central America. This has already happened at low to mid elevations on Savai'i, where native landsnail species are known to have declined and gone extinct, and introduced species have become abundant and widespread. However, the upland habitats on this island still support a rich and taxonomically-diverse native landsnail fauna of at least 50 native species, including at least 38 species that are probably local endemics. Further, no introduced landsnail species were found above c. 1,000 m elevation in the areas surveyed. The only other places in Polynesia where such rich native landsnail faunas are known to have survived largely intact are in montane habitats on Tahiti (Society Islands), and on some of the Hawaiian Islands.

One of the key findings of the present study was that although some native landsnail species were widely distributed in the upland habitats surveyed, the majority had highly restricted or sparse distributions. Preservation of the full range of upland landsnail biodiversity on Savai'i, and particularly of the locally-restricted endemic species, will thus be dependent on the protection of the remaining areas of unmodified native upland forest and shrubland in the central part of this island from road construction, logging, land development and alien plant invasions. It is also critically important that key alien predators not yet established on Savai'i, such as the snails *Euglandina rosea* and *Oxychilus* spp., and the Argentine ant, should not be introduced to this island either accidentally or as biocontrol agents.

6. SUGGESTED FURTHER WORK

1. The upland landsnail fauna of Savai'i is still poorly known. Further surveys are required to obtain a better understanding of the distribution and population status of the upland endemics in the vicinity of Mata o le Afi, and the composition of the fauna elsewhere along the Tuasivi Ridge, including in the vicinity of Mauga Elietoga, Mauga Mataulano, and south of Safune. The surveys should include sampling of arboreal microhabitats, including tree trunks, epiphytes, and perched litter trapped in epiphytes and tree forks.
2. Much of the historical Samoan landsnail material in the Bishop Museum (i.e., including extensive collections from Savai'i by Bryan in 1924, Christophersen in 1929 and 1931; and Robinson in 1994) has never been identified to species level, and the same applies to some material in the Field Museum of Natural History collected by Laurie Price and Alan Solem in 1965. It is likely that at least some of the unnamed landsnail species collected in the uplands in May 2012 are represented in these previous collections. The Samoan landsnail collections in the Bishop Museum and the Field Museum should be re-examined, un-named species identified, previous species identifications checked, and a comprehensive GIS-compatible database of all Samoan landsnail records compiled, to provide reliable information on the composition of the Samoan fauna, historical species distributions, and patterns of faunal changes.

ACKNOWLEDGEMENTS

I thank Bruce Jefferies, James Atherton, Suemalo Talie Foliga and So'oalo Tito Alatimu for organizing trip logistics; Fialelei Enoka for assistance with fieldwork; the Royal New Zealand Airforce for helicopter transport on Savai'i; the Samoan Ministry of Natural Resources and Environment for providing accommodation on Savai'i; Juvita Tone of the Samoan Ministry of Agriculture and Fisheries for providing information on *Platydemus manokwari*; Gary Barker for producing the species accumulation curve and species richness estimations; James Atherton for producing the map of historical collecting sites; and Eric Edwards and Greg Sherley for suggesting improvements to this report.

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Appendix 5.1 Landsnail species recorded from forest sites above 950 m elevation on Savai'i in May 2012

New species records for Savai'i are denoted by an asterisk (*). Non-native species introduced to Samoa since the late 1800s are listed in **bold type.**

HYDROCENIDAE

**Georissa* sp. 1

HELICINIDAE

Sturanya beryllina (Gould, 1847)]

**Sturanya* sp. 1

**Sturanya* sp. 2

**Sturanya* sp. 3

**Sturanya* sp. 4

**Sturanya* sp. 5

**Sturanya* sp. 6

NEOCYCLOTIDAE

Ostodes exasperatus Girardi, 1978

Ostodes garretti Clench, 1949

Ostodes llanero Girardi, 1978

**Ostodes* sp. 1

**Ostodes* sp. 2

**Ostodes* sp. 3

**Ostodes* sp. 4

**Ostodes* sp. 5

DIPLOMMATINIDAE

**Diplommatina* sp. 1

ASSIMINEIDAE

**'Assiminea'* sp. 1

Omphalotropis biliratus Mousson, 1865

Omphalotropis conoideus Mousson, 1865

**Omphalotropis* sp. 2

ACHATINELLIDAE

**Elasmias* sp. 1

VERTIGINIDAE

**Nesopupa* sp. 1

**Nesopupa* sp. 2

**Pupisoma* sp. 1

PARTULIDAE

**Eua* sp. 1

Samoana canalis (Mousson, 1865)

RHYTIDIDAE

**Delos* sp. 1

ENDODONTIDAE

**Thaumatodon* sp. 1

**Thaumatodon* sp. 2

CHAROPIDAE

**Discocharopa aperta* (Mollendorff, 1888)

Sinployea allecta (Cox, 1870)

*Charopidae sp. 1

*Charopidae sp. 2

*Charopidae sp. 3

*Charopidae sp. 4

*Charopidae sp. 5

*Charopidae sp. 6

*Charopidae sp. 7

PUNCTIDAE

*Punctidae sp. 1

*Punctidae sp. 2

*Punctidae sp. 3

EUCONULIDAE

Diastole lamellaxis Baker, 1938

Diastole schmeltziana var. *usurpata* (Mousson, 1869)

Lamprocystis perpolita (Mousson, 1869)

**Lamprocystis* sp. 1

**Lamprocystis* sp. 2

ZONITIDAE

Trochomorpha troilus var. *savaii* Baker, 1941

SUCCINEIDAE

Succinea putamen Gould, 1846

**Succinea* sp. 1

BRADYBAENIDAE

***Bradybaena similaris* (Rang, 1831)**

ANNEX 1

Preliminary report on the low- to mid-elevation landsnail fauna of Savai'i

FRED BROOK

INTRODUCTION

Savai'i is the largest and highest Samoan island (1718 km^2, 1870 m elevation), but previous knowledge of its landsnail fauna is poor compared to the other main islands in the group and, in particular, there is very little existing information on the fauna of the central range above c. 950 m. In May 2012 a multidisciplinary, reconnaissance ecological survey of the central range on Savai'i (i.e., the Tuasivi Ridge) was carried out to obtain information on the upland vegetation and fauna of this island. This survey was funded by the Critical Ecosystems Partnership Fund (CEPF), and was undertaken by the Secretariat for the Pacific Regional Environment Programme (SPREP), in partnership with the Ministry of Natural Resources and Environment (MNRE) and local communities on Savai'i. During this survey, the species composition and diversity of landsnail assemblages were determined at a series of forested sites on the Tuasivi Ridge, ranging from c. 990-1870 m in elevation. In addition, prior to this survey, the opportunity was taken to survey several coastal sites and one mid-elevation site on Savai'i to obtain information on: the composition and distribution of the introduced landsnail fauna; and the composition and history of recent changes in the lowland fauna. The present report describes the findings of the latter survey. The preliminary results of the landsnail survey of Upland Savai'i are given in chapter five of this BIORAP report.

Previous work on Samoan landsnails

The first descriptions of Samoan landsnails were by Gould (1846a-d; 1847a-c; 1852, 1856), based on material collected in 1839 during the United States Exploring Expedition. Mousson (1865, 1869) described many additional new species, and compiled annotated species lists, from collections made in Samoa during the 1860s by Eduard Graeffe. Cox (1870) and Baird (1873) described new species from material collected by John Brazier and Julius Brenchley, respectively, during a visit to Samoa by H.M.S. *Curacoa* in 1865. Garrett (1887) provided an overview of the Samoan landsnail fauna, listing many additional new records. Wagner (1905, 1907-11) listed and figured all the Samoan species of Helicinidae except those described by Baird (1873), and described several new species from Samoa.

Scientists from the Bishop Museum, Honolulu, made extensive collections of Samoan landsnails between the 1920s and 1940, including collections on Savai'i made by the entomologist Edwin Bryan in 1924, and the botanist Erling Christophersen in 1929 and 1931. Baker (1938, 1940, 1941) reviewed and figured the Samoan species of Euconulidae and Zonitidae, describing new species and subspecies; Cooke (1942) and Kondo (1943) listed the Samoan distribution of *Helix gradata* Gould; Clench (1949) reviewed the endemic Samoan genus *Ostodes*, describing three new species; and Cooke & Kondo (1961) recorded four achatinellid species from Samoa.

Laurie Price and Alan Solem from the Field Museum of Natural History, Chicago, made extensive collections of landsnails on Upolu and Savai'i in 1965, and on American Samoa in 1975 (Solem 1975). Solem (1976, 1983) reviewed the Samoan species of Charopidae and Endodontidae, and described a new charopid species from near Lake Mataulano on Savai'i. Girardi (1978) re-evaluated the taxonomy of *Ostodes*, and described three new species in this genus. Kirch (1993) described fossil landsnail assemblages from an early Polynesian occupation site on Ofu Island, American Samoa. In the 1990s, surveys and collections of landsnails were made on Upolu and Savai'i by Tony Robinson, and in American Samoa by Robert Cowie and Stephen Miller. Miller (1993) assessed the status of native landsnail species in American Samoa; Cowie (1998) compiled a catalogue of nonmarine snails and slugs of the Samoan Islands; recent changes in landsnail faunal composition and species abundances in American Samoa and Samoa were analysed by Cowie (2001a) and Cowie & Robinson (2003), respectively; a list of the introduced landsnail species from the Samoan islands was compiled by Cowie (2001b); the status of partulid tree snails in American Samoa was assessed by Cowie & Cook (2001); the landsnail faunas of some islands in American Samoa were described by Cowie & Rundell (2002) and Cowie *et al*. (2002); and the distribution of the Giant African Landsnail (*Achatina fulica*) on Savai'i was surveyed by the Samoan Ministry of Agriculture and Fisheries (Juvita Tone pers. comm. 2012).

The landsnail faunas of Upolu and American Samoa are now relatively well known, but the Savai'ian fauna, by contrast, has been less thoroughly studied. The locations of known historical landsnail collection sites on Savai'i, which are represented by specimens in the Bishop Museum and the Field Museum of Natural History, are shown in figure 1. The most recent faunal list compiled for this island (i.e., Cowie & Robinson 2003: table 1) comprised a total of c. 40 species only, including five species that were inferred to have been synanthropically introduced. By contrast, Cowie & Robinson (2003) listed c. 56 fully terrestrial gastropod species, including 10 introduced species, from the adjacent Samoan island of Upolu, which is considerably smaller and lower (i.e., 1125 km^2, 1143 m) than Savai'i. Most of the existing knowledge of the Savai'ian landsnail fauna was obtained from collections made in the lowlands and foothills, and almost nothing was known about the fauna of forest and shrubland habitats above c. 950 m elevation. Other poorly known aspects of the fauna included: the population status of endemic landsnail species; landsnail species composition and distributions in coastal habitats; the composition and distribution of the introduced landsnail fauna; and the composition of the micro-fauna (i.e., snails with maximum shell dimensions of <3 mm).

Aims of present study

As already noted, the main aim of the field survey on Savai'i in May 2012 was to obtain information on the composition and richness of the landsnail fauna in the forested uplands above c. 950 m elevation on Savai'i. Secondary aims, the results of which are described in this report, included:

1. The compilation of an updated list of landsnail species from low to mid elevation habitats on Savai'i, to provide a basis for comparison with the upland fauna from this island;
2. The opportunistic collection of information on the altitudinal ranges of, and habitats occupied by, introduced (i.e., non-native) landsnail species on Savai'i;
3. Obtaining information on patterns of recent changes in the lowland landsnail fauna on Savai'i, and particularly population trends of indigenous and endemic species, as determined from fossil assemblages in beach ridges and coastal dunes.

METHODS

An updated list of landsnail species from low- to mid-elevation habitats on Savai'i (i.e., 0-950 m) was compiled from the published literature (listed in the References), and incorporating new species records obtained at four coastal sites (Salimu, Aganoa Beach, Cape Asuisui, Tufutafoe) and one inland site at c. 880 m elevation above Asau (13.58884°S, 172.64801°W), during the 2012 field survey. Information on the historical and present-day distributions of introduced landsnail species on Savai'i were obtained from database records at the BPBM and FMNH, information provided by Juvita Tone, and observations made during the 2012 survey.

Sedimentary sequences containing fossil landsnail assemblages in ground soils and paleosols (i.e., buried soils) were found at four coastal sites on Savai'i: a borrow pit in a sandy beach ridge near Salimu (13.64186°S, 172.19171°W); the eroded seaward face of a sandy gravel beach ridge at Aganoa Beach (13.77239°S, 172.28713°W); a cutting through a transverse foredune near Cape Asuisui (13.80103°S, 172.52542°W); and borrow pits on a predominantly sandy beach ridge near Tufutafoe (13.52388°S, 172.79634°W). Stratigraphic and sedimentologic descriptions were compiled for the sequences exposed at each of these sites. Sediment samples of c. 4 litres volume were collected from the ground soils and paleosols at each site, and snail shells in these samples were separated and concentrated by flotation in water, sieving, and hand-sorting under a binocular microscope. At the Aganoa Beach, Alofaaga and Tufutafoe sites, samples of leaf litter were also collected and sorted under a microscope, and live snails were searched for by eye in the field. At each site, individual specimens of each landsnail species found were arbitrarily categorized as 'extant' if they were live snails or fresh, empty shells, and 'fossil' if they were old, bleached, empty shells. To analyse the faunal changes at these sites, the landsnail species found were assigned to one of three biogeographic categories: Samoan endemics; Pacific species; and Introduced species. The first category included species restricted to Samoa. The second category included species that have been recorded from more than one island group in Polynesia or the wider Pacific region. Most if not all these species are probably native to Samoa, but the possibility that some have been introduced cannot be discounted on present evidence (e.g., see comments on *Lamellidea oblonga* below). The populations of these species on Savai'i are cryptogenic *sensu* Carlton (1996), in that there is insufficient information to conclusively determine whether they are native or introduced. The third biogeographic category included species that are known or inferred to have been synanthropically introduced to Polynesia. Two species in this group (*Allopeas gracile*, *Gastrocopta pediculus*) were introduced to Samoa and other Polynesian island groups prior to European contact (e.g., Christensen & Kirch 1981, 1986; Kirch 1993; Preece 1998; Brook 2010), but the remainder have become established in Polynesia since the late 1800s to early 1900s. Patterns of faunal change at each site were examined by looking at stratigraphic (i.e., temporal) variation in the numbers of species present in each category and in species assemblages overall, and by looking at stratigraphic variation in the percentages of species within each category.

RESULTS

An updated list of landsnail species recorded from elevations of <950 m on Savai'i is given in Appendix 1. A previous faunal list for this island, compiled by Cowie & Robinson (2003: table 1), contained a total of c. 40 landsnail species, including five introduced species (i.e., *Allopeas gracile*, *Bradybaena similaris*, *Paropeas achatinaceum*, *Sarasinula plebeia*, *Subulina octona*). The present list contains 59 species and includes the following new records: the endemic Samoan species *Thaumatodon hystricelloides*, previously known from Upolu only; two undescribed species that are probably both endemic to Samoa (*Sinployea* sp. 1, *Sturanya* sp. 1); an unidentified species of *Omphalotropis* which is probably a Samoan or regional endemic; four widely distributed Pacific species (*Discocharopa aperta*, *Lamellidea oblonga*, *L. pusilla*, *Melampus luteus*); and ten introduced species (*Achatina fulica*, *Allopeas micra*, *Gastrocopta pediculus*, *G. servilis*, *Kororia palaensis*, *Laevicaulis alte*, *'Microcystina' gerritsi*, *Opeas hannense*, *Parmarion martensi*, *Pupisoma orcula*).

The records of *Omphalotropis* sp. 1, *Sinployea* sp. 1 and *Thaumatodon hystricelloides* were based on fossil shells found at coastal sites (below), and it is not known whether these three species are extant or extinct on Savai'i. *Sturanya* sp. 1 was found at c. 880 m elevation south of Asau, and in the central Savai'ian uplands (Brook 2012).

One of the newly recorded Pacific species, *Melampus luteus*, is restricted to supralittoral habitats, and is probably native to Savai'i. *Discocharopa aperta* and *Lamellidea pusilla* are cryptogenic species and may or may not be native to this island. Both these species are represented in pre-European fossil assemblages on Savai'i (below). By contrast, fossil evidence outlined below suggests that *Lamellidea oblonga* may have been introduced to Savai'i comparatively recently.

The new records of introduced species from Savai'i include one species that was introduced to Samoa prior to European contact (*Gastrocopta pediculus*), and nine species that were modern introductions (i.e., *Achatina fulica*, *Allopeas micra*, *Gastrocopta servilis*, *Kororia palaensis*, *Laevicaulis alte*, *'Microcystina' gerritsi*, *Opeas hannense*, *Parmarion martensi*, *Pupisoma orcula*). The majority of these new records were from coastal habitats. The exceptions were the slug *Laevicaulis alte*, which ranged from the coast to at least c. 880 m elevation on northwestern Savai'i; the semi-slug *Parmarion martensi*, found at the same site, and in logged forest at c. 800 m south of A'opo; and *Kororia palaensis*, found at c. 880 m elevation in logged forest above Asau. Ministry of Agriculture and Fisheries records indicate that *Achatina fulica* was widely distributed in the lowlands around Savai'i, locally extending up to c. 300 m elevation (Juvita Tone pers. comm. 2012).

Stratigraphic sections and soil horizons

Much of the coastline of Savai'i is fronted by basaltic lava flows, but narrow coastal plains comprising calcareous sandy beach ridges are present between Pu'apu'a and Tuasivi on the eastern coast; between Sasina and Safa'i; and at Fagasa and Papa on the northern coast; between Avata and Tufutafoe on the northwestern tip of the island; at Neiafu, Foailalo and Satuaitua on the western coast; and at Palauli on the southern coast (Kear & Wood 1959; Wright 1963). All of these sedimentary deposits potentially contain fossil assemblages that could provide information on the recent history of faunal and environmental changes in coastal habitats on Savai'i. During a very cursory reconnaissance in May 2012, stratigraphic sections containing paleosols (i.e., buried soils) and fossil landsnail assemblages were found at two sites within coastal plains on Savai'i: in a borrow pit on the landward side of the main road near Salimu; and in a series of borrow pits on the seaward side of the road between Tufutafoe and Cape Mulinu'u.

The sequence exposed near Salimu consisted of a 25 cm-thick, moderately humic- and charcoal-stained, grey-brown, fine-grained sandy ground soil and an underlying 20 cm-thick, moderately humic-stained, medium brown, fine-grained sandy paleosol, separated by a 30-70 cm-thick interval of unweathered, stratified, bioclastic fine-grained sand. The paleosol was underlain by >30 cm of unweathered, bioclastic fine- to medium-grained sand. The stratified unweathered sand between the two soils was presumably a storm deposit or tsunami deposit. The borrow pit at this site was located in a highly modified landscape of open grassland and scattered trees at the edge of a village.

The sequence exposed northwest of Tufutafoe included three separate soils: a 15 cm-thick, weakly humic-stained, medium brown, fine- to medium-grained sandy ground soil, overlying a 30-50 cm-thick unit of unweathered, fine- to medium-grained sand; an upper paleosol, 15 cm thick, of moderately humic- and charcoal-stained, fine- to medium-grained sand, overlying a 12 cm-thick interval of weakly humic-stained fine sand; and a lower paleosol > 30 cm thick, of moderately humic- and charcoal-stained, fine- to medium-grained sand. The ground soil and underlying unweathered sand unit contain scattered, matrix-supported clasts of coral and reef limestone up to boulder size, and the two paleosols and the intervening sand unit also contain scattered coral clasts. The gravelly sand facies in this section probably represent at least three separate storm or tsunami deposits, upon each of which soils subsequently developed. The modern vegetation at this site consisted of low forest of *Hibiscus tiliaceus*, with one old, emergent tree of *Hernandia nymphaeifolia*, and scattered coconut (*Cocos nucifera*) palms, bounded to seaward by *Scaevola taccada* shrubland.

In addition to the two coastal plain sites, fossil assemblages were also found in a small coastal spit near Aganoa Beach, and in a transverse dune ridge on the coast near Cape Asuisui. The former site comprised a beach ridge of sandy gravel overlying an intertidal platform of basaltic conglomerate beach rock, and backed by a crab-burrowed sand flat slightly above high tide level. A section exposed in the eroded seaward (i.e., southwestern) face of the beach ridge included two soils: a 40 cm-thick, weakly humic-stained, medium brown, sandy and gravelly ground soil; overlying a 12-20 cm-thick, strongly charcoal-stained, blackish-brown, gravelly sand paleosol. Both these soils contained abundant, clast-supported pebble to cobble-size bioclasts (including coral fragments and marine mollusk shells), and scattered rounded basalt pebbles. The paleosol overlay >30 cm of unweathered, sandy granule-pebble bioclastic gravel, with scattered basalt pebbles. The exposed base of the bioclastic gravel sequence was at or close to high water mark (hwm). The present-day vegetation at this site consisted of tall coastal forest dominated by *Barringtonia asiatica*, with uncommon coconut palms, *Hernandia nymphaeifolia* and *Terminalia catappa* on the beach ridge, and forest of *Inocarpus fagifer* on the sand flat to landward.

The dune ridge near Cape Asuisui had a crest up to c. 3.5 m above hwm. Sections showing the internal stratigraphy were exposed in the wave-eroded seaward face, and in cuttings through the dune. Two soils were exposed: a 20 cm-thick, moderately humic- and charcoal-stained, grey, fine sandy ground soil; and a 30 cm-thick, weakly humic-stained, medium brown, fine sandy paleosol, containing scattered, beach-worn coral fragments, marine mollusc shells and basalt pebbles; separated by a lens up to 1 m thick, of unweathered fine sand. The two soil horizons amalgamated in the landward part of the dune. The paleosol overlay >1 m of unweathered fine sand, and the ground soil was locally overlain by up to c. 15 cm of unweathered, wind-blown fine sand. The exposed base of the dune sequence at this was c. 1 m above high water mark. The present-day vegetation at this site consisted of coconut palms and a ground layer of *Ipomoea pes-caprae* on the seaward part of the dune ridge, and forest of *Barringtonia asiatica*, *Calophyllum inophyllum* and coconut palms on the landward part.

The ages of the soils sampled during the present study have not been determined directly, but all lie within sedimentary sequences that almost certainly formed after the mid- to late Holocene highstand, when sea level in the Samoan region is estimated to have been c. 1.8 m above the present level (see Dickinson 2009: figure 5). If this interpretation is correct, it follows that the coastal plain deposits at Salimu and Tufutafoe, the coastal spit at Aganoa Beach, and the dune ridge at Cape Asuisui, probably all formed within the last several hundred years, with age ranges spanning the period preceding and following European contact.

Faunal changes at coastal sites

Changes in the biogeographic composition of landsnail assemblages at the Salimu, Aganoa Beach, Cape Asuisui and Tufutafoe sites are shown in figures 2-5. The fossil assemblages within the paleosols at the three first-mentioned sites contained mixtures of Samoan endemics, Pacific species, and the introduced species *Allopeas gracile* and *Gastrocopta pediculus*. This suggests that these fossil assemblages accumulated prior to European contact and/or during the early to mid 1800s, before any of the alien (i.e., non-native) landsnail species introduced as a result of modern commerce became established on Savai'i. By contrast, the upper paleosol at the Tufutafoe site contained old, worn shells of *Bradybaena similaris*, *Opeas hannense*, *Paropeas achatinaceum* and *Subulina octona*, so presumably formed, at least in part, during the early-mid 1900s. The lower paleosol at this site contained common shells of *Opeas hannense*, but as this species is known to be partly subterranean in habit (Brook 2010), it is not clear if these shells are the same age or younger than the enclosing soil. This paleosol is presumably of similar age to the paleosols sampled at Salimu, Aganoa Beach and Cape Asuisui.

Landsnail species composition and richness differed between the four coastal sites that were examined during the present study, but all the sites had broadly similar recent faunal histories, characterized by extirpation of Samoan endemics and some or all the Pacific species, and their replacement by introduced species. Loss of Pacific species was highest at the Salimu and Tufutafoe sites, which also had the most synanthropically modified modern habitats. By contrast, several Pacific species (e.g., *Assiminea parvula*, *Lamellidea pusilla*, *Liardetia samoensis*, *Pythia scarabaeus*, *Sturanya fulgora*) were still extant in the native coastal forest remnants at the Aganoa Beach and Cape Asuisui sites.

Fossil shells of the Polynesian introductions *Allopeas gracile* and *Gastrocopta pediculus* were ubiquitous in paleosols and groundsoils at the four coastal sites examined, and were extant at all except the Salimu site. The Pacific species *Lamellidea oblonga* is also generally thought to have been synanthropically spread throughout Polynesia in prior to European contact, following the interpretation of Cooke & Kondo (1961). However, this species was not found in any of the paleosols examined on Savai'i, and its first (and only) appearance was in a ground soil at Tufutafoe, which suggests that it was only recently introduced to Savai'i. No snails or fresh shells of *L. oblonga* were found at the Tufutafoe site, and it is possibly no longer extant there. The most frequent modern introductions in extant assemblages were: *Gastrocopta servilis*, *'Microcystina' gerritsi*, *Opeas hannense*, *Quickia concisa* (4 sites each); *Allopeas micra* and *Subulina octona* (3 sites each); and *Paropeas achatinaceum* (2 sites).

One endemic species (*Sinployea allecta*) and several Pacific species (i.e., *Assiminea parvula*, *Discocharopa aperta*, *Lamellidea pusilla*, *Liardetia samoensis*, *Nesopupa goddefroyi*, *Pythia scarabaeus*, *Sturanya fulgora*) were evidently formerly characteristic and widely distributed members of coastal landsnail assemblages on Savai'i. Other species were more patchily distributed in coastal habitats: *Omphalotropis* sp. 1 was found at the Cape Asuisui and Tufutafoe sites only; *Lamprocystis upolensis* and *Thaumatodon hystricelloides* were found at the Aganoa Beach site only; and *Sinployea* sp. 1 was found at the Cape Asuisui site only. Among the other Pacific species: *Delos gradata* was found at the Aganoa Beach and Cape Asuisui sites only; and *Sturanya musiva* was found at the Tufutafoe site only. Interestingly, the latter species and its congener *Sturanya fulgora* had non-overlapping distributions at the four coastal sites examined during the present study. Some landsnail species in the fossil assemblages were represented by one or a few juvenile shells only and thus were probably vagrants or had populations living in adjoining areas. This group included: an unidentified species of *Succinea* at the Salimu site; unidentified species of *Eua* and *Ostodes* at the Aganoa Beach site; *Omphalotropis conoideus* at the Cape Asuisui and Tufutafoe sites; and *Sturanya beryllina* at the Tufutafoe site.

DISCUSSION

A total of 59 landsnail species is now known from low- to mid elevations on Savai'i, including at least 13 alien species that have been introduced to this island since the late 1800s. The fact that surveys of four coastal sites and one inland site yielded 18 new species records suggests that the composition and richness of the low- to mid-elevation landsnail fauna of Savai'i is still incompletely known, particularly with regard to minute species and alien species. In addition, very little is known about the current population status of endemic and indigenous landsnail species in low- to mid-elevation habitats on Savai'i, and on the distribution and ecological effects of introduced landsnail species on this island.

Over the last 150 years or so many species of indigenous and endemic landsnails on tropical Pacific Islands have declined and gone extinct as a result of the loss or modification of native forest and shrubland habitats, predation by newly introduced alien species, and probably also as a result of diseases transmitted by introduced landsnails. Environmental changes in the lowlands and foothills on Savai'i over this period have included the loss of most of the former extensive native forest cover as a result of logging, fires, and land clearance for settlements, horticulture, pastoral farming, coconut plantations, and exotic forestry plantations. In addition, many of the remaining areas of native forest have been modified by weed invasion, trampling and browsing by cattle, and cyclone damage. Exotic predators that became established on Savai'i over this period, included mice (*Mus musculus*), Ship rats (*Rattus rattus*), geckos (*Gehyra mutilata*, *Hemidactylus frenatus*) and many species of ants (Wilson & Taylor 1967; Gill 1993; Wetterer & Vargo 2003; James Atherton pers. comm.. 2012). Among the latter are highly invasive species, including *Anoplolepis gracilipes*, *Paratrechina longicornis*, *Pheidole megacephala* (Wilson & Taylor 1967), that are known or inferred to have caused declines and extinctions of native invertebrates on other tropical islands (see Brook 2010: 231 for literature references). Another exotic predator, the flatworm *Platydemus manokwari*, was first recorded on Savai'i in 1998, at the villages of Asau, Gataivai, Lano, Lefagaoali'i, Mauga, Samata and Tafua (Juvita Tone pers. comm. 2012). This species was presumably purposely introduced to Savai'i in 1996-98 as a biocontrol agent targeting local populations of *Achatina fulica*. Further introductions of *P. manokwari* were carried out in 2001 by the Ministry of Agriculture and Fisheries to A'opo, Asau (airport), Fa'ala, Faga, Falealupo, Lata plantation, Maota, Neiafu, Palauli, Papa Sataua, Sasina, Sasuiatua, Taga, Tapueleele, Tufutafoe, Vai'a'ata and Vaipouli (Juvita Tone pers. comm. 2012). The introduction and spread of *P.manokwari* on other tropical Pacific islands has resulted in declines and extinctions of native arboreal and ground-dwelling landsnail species (e.g., Hopper & Smith 1992; Sugiura *et al*. 2006; Ohbayashi *et al*. 2007; Sugiura *et al*. 2009; Iwai *et al*. 2010). No individuals of this flatworm species were seen on Savai'i during the present survey, and its present distribution and abundance on this island are not known. It may not yet have spread far from the release sites, but if it invades native shrubland and forest on Savai'i, as it has on other Pacific islands, it will undoubtedly cause serious declines and possibly extinctions of the local native landsnail species.

Fossil assemblages at the four coastal sites examined during the present study provide clear evidence of the local extirpation of landsnail species on Savai'i during historic time. The landsnail die-offs at the Salimu and Tufutafoe sites probably resulted largely or solely from clearance of former coastal forest tracts. However, the die-offs at the Aganoa Beach and Cape Asuisui sites took place within native coastal forest remnants, and thus must have had other causes, with predation being the most likely one. Some of the landsnail species present in the coastal fossil assemblages are not represented in any of the extensive historical collections made on Savai'i from the early 1920s onwards, and thus may have become extinct on this island.

The status of the Samoan landsnail fauna has previously been assessed by Cowie & Robinson (2003), based on qualitative evaluations of changes in species distribution and/or abundance during the twentieth century, as determined from comparisons of museum collections made pre-1965 (BPBM), during 1965 (FMNH), and in the 1990s (BPBM). These authors concluded that seven of the native and cryptogenic species reported from Savai'i had declined during the twentieth century (i.e., *Assiminea parvula*, *Delos gradata*, *Liardetia samoensis*, *Nesopupa goddefroyi*, *Ostodes savaii*, *Samoana stevensoniana*, *Sturanyna musiva*), ten species had 'possibly' or 'probably' declined (i.e., *Diastole schmeltziana*, *Diplommatina problematica*, *Eua expansa*, *Ostodes gassiesi*, *O. upolensis*, *Samoana canalis*, *Sinployea allecta*, *Sturanya fulgora*, *Sturanya plicatilis*, *Trochomorpha apia*), and one species had possibly increased (i.e., *Sturanya beryllina*). Cowie & Robinson (2003) noted that some other species showed no clear trend, and suggested that some other species, which could not be evaluated because of a lack of records, were possibly extinct.

Cowie & Robinson (2003: 62) acknowledged that the differences in sample locations and collection methods precluded rigorous comparisons of the pre-1965, 1965 and 1990s data sets. In particular, their methodology could not reliably determine whether differences in the abundance of particular species between the various data sets resulted from island-wide population changes, biogeographic factors, or from a combination of both temporal and spatial variation. In addition, differences in collection methods almost certainly influenced these authors' findings with regard to the putative population trends of some minute landsnail species, including *Assiminea parvula*, *Diplommatina problematica* and *Nesopupa goddefroyi*. The pre-1965 landsnail collections consisted mainly of material collected by eye but also included some minute species sorted from litter samples, whereas the 1965 and 1990s collections were made by eye only, and were strongly biased towards, or consisted solely of, larger species. The size bias of previous collections from Savai'i is clearly indicated by the absence of historical records and museum collections of the minute species *Discocharopa aperta, Gastrocopta pediculus* and *Lamellidea pusilla*, which are here shown to have been present in lowland habitats on this island since before European contact.

Cowie & Robinson (2003: table 1) separately listed the numbers of sites at which the various landsnail species were collected on Savai'i and Upolu in 1965 and the 1990s, but did not differentiate between these two islands when listing the species status pre-1965, and in assessing population trends during the twentieth century. Although some species may have had similar pre-1965 patterns of abundance and similar overall population trends on both Savai'i and Upolu, other species evidently did not. For example, *Assiminea parvula*, *Delos gradata*, *Liardetia samoensis*, *Sturanya musiva* and *Sturanya fulgora* may have been widespread and common/abundant on Upolu prior to 1965, but the BPBM collection database indicates that these species were collected at very few sites on Savai'i in 1924 and 1929-31. Conversely, some of the species that Cowie & Robinson (2003) listed as being in 'possible' or 'probable' decline, were actually collected at more sites on Savai'i in 1994 than in 1965 (e.g., *Eua expansa*, *Sturanya fulgora*, *Trochomorpha apia*).

Population status of native landsnails on Savai'i

Some native landsnail species previously known only from low and/or mid elevations on Savai'i were found to be moderately to very widespread and locally common in upland habitats above 950 m during the present survey. This group included the Samoan endemics *Diastole lamellaxis*, *Diastole schmeltziana* var. *usurpata*, *Lamprocystis perpolita*, *Ostodes garretti*, *Ostodes exasperatus*, *Ostodes llanero*, *Succinea putamen* and *Trochomorpha troilus* var. *savaii* (Brook 2012). During the 1994 survey on Savai'i, all of these species were either recorded at very few sites or were not found at all (Cowie & Robinson 2003). Their present status at low to mid elevations on Savai'i is not known.

Two native landsnail species that were relatively frequent at low to mid-elevation sites on Savai'i in 1994, namely *Omphalotropis conoideus* and *Sturanya beryllina*, were also found in upland habitats during the present study (Brook 2012).

The newly recorded species *Sturanya* sp. 1 is presently known only from upper foothill and upland habitats on Savai'i, at and above c. 880 m elevation.

Other landsnail species previously recorded from Savai'i, and some species found during the present survey as fossils only, are/were probably largely or entirely restricted to low and/or mid elevation habitats on this island. Fossil shells of *Lamprocystis upolensis* were common in a ground soil at Aganoa Beach; this species was recorded from Savai'i by Mousson (1869), but there are no subsequent records and apparently no other collections of it from this island. Three other species, *Omphalotropis* sp. 1, *Sinployea* sp. 1 and *Thaumatodon hystricelloides*, were also present as fossils in soils at coastal sites on southern and western Savai'i, but there have been no historical collections or reports of any of these species from this island. The scant available evidence thus suggests that all four of these species were relatively scarce on Savai'i by the late 1800s and some or all may now be extinct on this island. *Thaumatodon hystricelloides* has also undergone a marked recent decline on Upolu: in the mid-late 1800s this species was reportedly "not uncommon" (Garrett 1887: 130), but by the mid 1960s it was restricted to a few sites above c. 540 m elevation (Solem 1983: 455).

The fossil assemblages examined during the present study indicate that *Assiminea parvula*, *Delos gradata*, *Discocharopa aperta*, *Lamellidea pusilla*, *Liardetia samoensis*, *Pythia scarabaeus*, *Sinployea allecta*, *Sturanya fulgora* and *Sturanya musiva* were all formerly locally common in coastal habitats on Savai'i, but have died out across at least parts of their former distribution areas. Historical records (or a lack of) suggest that these species were all relatively scarce on Savai'i in 1924-31, 1965 and 1994. At least seven of these species were still extant on Savai'i in 2012: *Assiminea parvula*, *Lamellidea pusilla*, *Liardetia samoensis*, *Pythia scarabaeus* and *Sturanya fulgora* were living at the coastal sites at Aganoa Beach and Cape Asuisui; and rare individuals of *Discocharopa aperta* and *Sinployea allecta* were found in upland habitats above 950 m. Whether *Delos gradata* and *Sturanya musiva* are also still extant on Savai'i is not known at present.

The endemic species *Diastole savaii* was found at a single site only during the present survey, in forest south of A'opo at c. 800 m elevation. Museum records indicate that this species has been relatively scarce since at least the early 1900s.

Cowie & Robinson (2003) suggested that the partulid species *Eua expansa*, *Samoana canalis* and *S. stevensoniana* were all in decline on Savai'i, though their data indicate that *E. expansa* was still relatively frequent on this island in 1994. During the present survey, *E. expansa* and *S. stevensoniana* were found at one site only, in logged forest at c. 880 m elevation above Asau. *Samoana canalis* was found at the same site, and also had a patchy distribution in logged forest at c. 800-990 m elevation above A'opo. These three species are endemic to Savai'i and Upolu, and have evidently been more frequent on the former than the latter throughout the twentieth century (Cowie & Robinson 2003: table1).

Eight endemic Samoan species previously recorded from Savai'i were not found during the present survey, and their current population status on this island is not known. Four of these species are known from single sites only: the minute, ground-dwelling species *Diplommatina problematica* was collected in lowland forest between Sataua and Fatelima in 1929 (BPBM); *Graeffedon savaiiensis* is known from a single shell collected in forest near Lake Mataulano in 1929 (Solem 1983); and *Omphalotropis bifilaris* and *Ostodes upolensis* are each known from single specimens collected in forest above Sala'ilua in 1965 (FMNH; Girardi 1978). The other four species were all more widely distributed. *Ostodes gassiesi* has been recorded from the eastern and southeastern lowlands, and the southern and southeastern foothills, at 75-450 m elevation (Girardi 1978). *Ostodes savaii* has been recorded from the eastern, south eastern and southwestern lowlands, and the western, southern and southeastern foothills, at 150-450 m elevation (Girardi 1978). Museum collections indicate that *Sturanya plicatilis* was widely distributed on Savai'i in the early and mid 1900s (BPBM, FMNH), but Cowie & Robinson (2003) reported that this species was relatively scarce, and possibly in decline, by the late 1900s. Collections in the BPBM indicate that *Trochomorpha apia* was relatively widely distributed on Savai'i in 1924-31 and in 1994, but this species is not represented at all in the collections made on Savai'i in 1965 (FMNH). Cowie & Robinson (2003) concluded that *T. apia* was probably in decline, and this was undoubtedly true for the populations on Upolu, and Tutuila in American Samoa (Miller 1993; Cowie 2001a). However, data given by Cowie & Robinson (2003: table1) indicate that *T. apia* was collected at many sites on Savai'i in 1994, which suggests that the population on this island was less threatened than those on Upolu and Tutuila.

Alien landsnails

One of the key findings of the present study is that there are many more alien landsnail species established on Savai'i than previously recognized. On the basis of the existing, admittedly sparse, information, it appears that some of these species were restricted to native and modified habitats at low elevations (e.g., *Allopeas micra*, *Gastrocopta servilis*, '*Microcystina' gerritsi*, *Opeas hannense*, *Quickia concisa*), whereas others ranged from the coast up into native and modified habitats at mid elevations. The latter group included: *Achatina fulica*, found up to at least 300 m elevation; *Sarasinula plebeia* and *Subulina octona*, found up to at least 450 m (BPBM); *Laevicaulis alte* and *Paropeas achatinaceum*, found up to at least 880 m; and *Bradybaena similaris*, found up to c. 1000 m. Two alien species were found at mid elevations only: *Parmarion martensi*, at c. 800-880 m; and *Kororia palaensis* at c.880 m; but both species were probably present at lower elevations as well.

None of these species were recorded by Mousson (1865, 1869) or Garrett (1887), which suggests that most, if not all of them, became established in Samoa after the late 1880s. Museum database records indicate that *Subulina octona* became established on Savai'i sometime before 1920. This species was present in mid elevation forest above Safune in 1924 (BPBM), and was widely distributed in low and middle elevation forests in 1931 (BPBM), 1965 (FMNH) and 1994 (BPBM). *Paropeas achatinaceum* became established on Savai'i sometime before the mid 1920s. This species was present locally in low elevation forests near Satana and Taga in 1929 (BPBM), and was widespread in low and mid elevation forests in 1965 (FMNH) and 1994 (BPBM). *Bradybaena similaris* was present on Upolu by 1923 (BPBM), but it is not represented in any of the museum collections made on Savai'i between 1924 and 1931. This suggests that it was introduced to Savai'i somewhat later, probably in the mid 1900s. *Bradybaena similaris* was widely distributed in low and mid elevation forests on Savai'i in 1965 (FMNH) and 1994 (BPBM). *Sarasinula plebeia* was established on Upolu before 1918 (Simroth 1918 – as *Vaginulus samoana*), but is not represented in any of the museum collections made on Savai'i between 1924 and 1965. It was first recorded on Savai'i in 1994, in low and mid elevation forests on the northern and northeastern sides of the island (BPBM). The available historical records thus suggest that *Sarasinula plebeia* became established on Savai'i in the mid to late 1900s. *Quickia concisa* was apparently introduced into Polynesia in the late 1900s (Brook 2010), and was first recorded on Savai'i in 1994 (BPBM; Cowie & Robinson 2003 – as *Succinea modesta*; Brook 2010).

Some of the alien species first recorded during the present study have probably been present on Savai'i for at least several decades, and have gone undetected because of their small size and/or restricted distributions. This includes *Allopeas micra*, *Gastrocopta servilis*, *Opeas hannense* and *'Microcystina' gerritsi*, which were all established elsewhere in Polynesia by the early 1900s, or in the case of *O. hannense*, by the late 1800s (Brook 2010). The large slug species *Laevicaulis alte* and *Parmarion martensi* presumably would have been found on Savai'i during earlier surveys had they been present, and thus probably did not become established on this island until the late 1900s. *Laevicaulis alte* was present on some western Pacific islands and Hawai'i by 1900, but apparently was not introduced into southeastern Polynesia until several decades later. In Samoa this species was first recorded near Apia, Upolu, in the early 1960s (Alicata & McCarthy 1964), and it probably became established on Savai'i some time after that. *Parmarion martensi* was first reported from the tropical south Pacific in the late 1900s. It was established in Fiji (Viti Levu) by 1979 (Brodie *et al*. 2010), and in the Samoan Islands of Tutuila and Upolu by 1992 (Miller 1993; Cowie & Robinson 2003). Museum records suggest that *Kororia palaensis* was also introduced to Polynesia relatively recently (Brook 2010), and this species probably did not become established on Savai'i until the late 1900s. *Achatina fulica* was first recorded in American Samoa in 1977 (Eldredge 1988, Miller 1993), on Upolu in 1990 (Cowie 1998), and on Savai'i at Sale'aula in 1996 (Juvita Tone pers. comm. 2012).

Some of the alien landsnail species present on Savai'i pose risks to the island's horticulture, and human and livestock health. The herbivorous species *Achatina fulica*, *Bradybaena similaris*, *Laevicaulis alte*, *Parmarion martensi* and *Sarasinula plebeia*, have the potential to become serious crop pests on Savai'i, as in other tropical locations (e.g., Godan 1983 [*B. similaris*, *L. alte*, *P. martensi*]; Raut & Barker 2002 [*A. fulica*]; Rueda *et al*. 2002 [*S. plebeia*]; Herbert & Kilburn 2004 [*L. alte*]; Robinson & Hollingsworth 2004 [*S. plebeia*]; Brodie & Barker 2011). All these species, along with *Paropeas achatinaceum* and *Subulina octona*, can also act as vectors for parasitic nematodes, including the rat lungworm, *Angiostrongylus cantonensis*, which can cause eosinophilic meningoencephalitis in humans (e.g., Alicata 1965; Alicata & McCarthy 1964; Wallace & Rosen 1969; Ash 1976; Hollingsworth *et al*. 2007). This species of lungworm was not found during a survey in the vicinity of Apia, on Upolu, in the early 1960s (Alicata & McCarthy 1964), but it had become established on Upolu and in American Samoa by the early 1980s (Kliks *et al*. 1982; Mark Bonin pers. comm.. 2012), and is presumably now present in rats and snail populations on Savai'i as well.

On some other tropical Pacific Islands predation by alien landsnails, and especially by *Euglandina rosea* (Férussac), is known or inferred to have caused declines and extinctions of native landsnail species, particularly in Achatinellinae and Partulidae (e.g., Hadfield 1986; Murray *et al*. 1988; Griffiths *et al*. 1993; Hadfield *et al*. 1993; Cowie & Cook 2001; Coote & Loeve 2003). Pathogens introduced with alien landsnail hosts may also have contributed to native species declines. At present no exclusively carnivorous alien landsnails are known from Savai'i, but *Paropeas achatinaceum* and some or all the other subulinid species present may be facultative predators of ground-dwelling native landsnail species on this island (see Naggs 1994). It is not known if introduced pathogens have caused or contributed to declines of native landsnail species in Savai'i or elsewhere in Samoa, but further introductions of alien landsnail species would obviously pose a potential risk to the native biota, and should be prevented as far as possible. Of particular concern is the risk that *Euglandina rosea*, or other predatory alien landsnail species already established in the tropical Pacific (e.g., *Deroceras laeve*, *Gonaxis kibweziensis*, *Gulella bicolor*, *Oxychilus alliarius*, *Streptostele musaecola*) will be intentionally or accidentally introduced to Savai'i from other Samoan islands or elsewhere. These species would undoubtedly cause serious declines and probably extinctions of native landsnail species on Savai'i.

CONCLUSIONS

The landsnail fauna at low to mid elevations (0-950 m) on Savai'i is much richer than previously recognized. It includes at least 59 species, of which 18 are new records. The latter group includes three species that are endemic to Samoa (*Sinployea* sp. 1, *Sturanya* sp. 1, *Thaumatodon hystricelloides*); several cryptogenic species with wider Pacific distributions; one non-native species that was introduced into Polynesia prior to European contact (*Gastrocopta pediculus*); and nine 'alien' species that have been introduced into Polynesia since European contact (i.e., *Achatina fulica*, *Allopeas micra*, *Gastrocopta servilis*, *Kororia palaensis*, *Laevicaulis alte*, *'Microcystina' gerritsi*, *Opeas hannense*, *Parmarion martensi*, *Pupisoma orcula*). The majority of the Pacific species are probably indigenous to Savai'i, but fossil evidence suggests that one species, *Lamellidea oblonga*, was a recent introduction to this island. Three of the new records (i.e., *Omphalotropis* sp. 1, *Sinployea* sp. 1, *Thaumatodon hystricelloides*) are based on fossil shells from coastal soils, and it is not known at present whether these species are still extant or have gone extinct on Savai'i.

Historical records indicate that some 'alien' landsnail species were established on Savai'i by the early 1900s (e.g., *Paropeas achatinaceum*, *Subulina octona*), whereas others became established in the mid to late 1900s (e.g., *Achatina fulic*a, *Bradybaena similaris*, *Kororia palaensis*, *Laevicaulis alte*, *Quickia concisa*, *Sarsinula plebeius*). Observations made during the May 2012 survey, indicated that alien landsnail species were widespread and locally common in native and anthropically-modified habitats up to c. 900-1,000 m elevation on Savai'i, but none were found in upland habitats above c. 1,000 m.

During the historic period there has been widespread and extensive loss and modification of lowland and mid elevation forests on Savai'i, which has undoubtedly caused marked declines and fragmentation of populations of most if not all the endemic and indigenous landsnail species that occupied these habitats. Fossil assemblages provide evidence of the local extirpation and possible extinction of some native species in coastal habitats, and museum collections hint at island-wide species declines. However, it is encouraging to note that the survey by Cowie & Robinson (2003) found that many of the landsnail species recorded from Savai'i in the early and mid-twentieth century were still extant in native forest remnants in the mid 1990s, and that some species were still relatively widely distributed and locally common at that time. The very limited observations made during the present study showed that some native landsnail species have persisted in areas of logged, degraded forest at mid-elevations, and that some cryptogenic 'Pacific' species were still locally common in some coastal forest remnants on Savai'i. Many of the endemic, indigenous and cryptogenic landsnail species on Savai'i appear to be restricted to low- and/or mid-elevation habitats, and their continued survival on this island will presumably depend, at least in part, on preservation of the remaining areas of native lowland and mid-elevation forest.

Exotic predators also pose a significant threat to the native landsnail fauna and some of the alien species already present, including rats, lizards, ants and landsnails, have probably contributed to declines, and possibly also extinctions, of some native landsnail species on this island. The recently introduced flatworm *Platydemus manokwari*, which has caused declines and extinctions of native landsnail species on other tropical Pacific islands, poses a serious new threat to the native landsnail fauna of Savai'i. Also of particular concern is the risk that the snail *Euglandina rosea* will be introduced to Savai'i intentionally or accidentally from other Samoan islands or elsewhere. This predatory species is notorious for having caused the decline and extinction of numerous native snail species on tropical Pacific islands, and would undoubtedly do the same on Savai'i. There are also many other 'alien' predatory species that are widely distributed in the Pacific region, and which could pose a serious threat to native landsnail species on Savai'i should they become established on this island. This includes tropical species, such as the fire ants *Solenopsis geminata* and *Wasmannia auropunctata*, snails in the family Streptaxiidae, and temperate species of ants (e.g., the Argentine ant *Linepithema humile*) and landsnails (e.g., *Deroceras laeve*, *Oxychilus* spp.), which potentially could invade the cooler mid-elevation and upland habitats on Savai'i.

SUGGESTED FURTHER WORK

1. Many of the landsnail species described from Samoa between the mid 1800s and early 1900s were poorly illustrated, or not illustrated at all. This has resulted in confusion over the identity of several species, particularly in the families Assimineidae, Helicinidae and Succineidae. This taxonomic confusion could be resolved by the compilation of a reference set of high-quality photographic images of type specimens of the Samoan land snail species described by Baird, Cox, Gould, Mousson and Wagner, from type collections in the Natural History Museum (London), Australian Museum (Sydney), Museum of Comparative Zoology (Harvard University), Zoological Museum (Zurich), and the Museum and Institute of Zoology of the Polish Academy of Sciences (Warsaw), respectively.
2. Much of the historical Samoan landsnail material in the Bishop Museum (i.e., including extensive collections from Savai'i by Bryan in 1924, Christophersen in 1929 and 1931; and Robinson in 1994) has never been identified to species level, and the same applies to some material in the Field Museum of Natural History collected by Laurie Price and Alan Solem in 1965. The collections of Samoan landsnails in the Bishop Museum and the Field Museum should be re-examined, un-named species identified, previous species identifications checked, and a comprehensive GIS-compatible database of all Samoan landsnail records compiled, to provide reliable information on the composition of the Samoan fauna, historical species distributions, and patterns of faunal changes.
3. A rapid survey of native and modified habitats below c. 950 m elevation on Savai'i should be carried out to determine the current distribution, altitudinal ranges, and abundance of native and introduced landsnail species, and in particular, the conservation status of the endemic species that are largely or entirely restricted to low- to mid-elevation habitats (e.g., including *Diastole savaii*, *Diplommatina problematica*, *Eua expansa*, *Graeffedon savaiiensis*, *Lamprocystis upolensis*, *Omphalotropis bifilaris*, *Ostodes gassiesi*, *Ostodes savaii*, *Ostodes upolensis*, *Ostodes* sp. 1, *Samoana canalis*, *Samoana stevensoniana*, *Sinployea allecta*, *Sturanya plicatilis*, *Trochomorpha apia*).
4. Further investigation of fossil assemblages in Holocene beach ridges and dune sequences on Savai'i, and in beach ridges on Upolu (e.g., the sequences with sand-soil couplets reported by Richmond *et al*. 2011), would lead to a better understanding of the composition and diversity of Samoan coastal landsnail faunas in late prehistoric time, and the nature and history of faunal changes over the last few hundred years. It would also provide information on the history and frequency of storm and tsunami-related inundation and sediment deposition at coastal sites on Savai'i and Upolu during the last several hundred years, relevant to coastal planning and hazard risk analysis

ACKNOWLEDGEMENTS

I thank the Samoan Ministry of Natural Resources and Environment for providing accommodation on Savai'i; Eric Edwards for assistance with fieldwork; Regina Kawamoto and Jochen Gerber for landsnail database records from the Bishop Museum and Field Museum of Natural History, respectively; Juvita Tone of the Samoan Ministry of Agriculture and Fisheries for providing historical records of *Achatina fulica* and *Platydemus manokwari* on Savai'i; James Atherton and Mark Bonin for information about other introduced species on Savai'i; James Atherton for producing the map of historical collecting sites; and Greg Sherley for suggesting improvements to this report.

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Appendix 1 List of landsnails recorded from lower to mid elevations (0-950 m) on Savai'i, Samoa

Data sources are given in square brackets after each species listing. New species records for Savai'i are denoted by an asterisk (*). Introduced species are shown in **bold** type.

HELICINIDAE

Sturanya beryllina (Gould, 1847) [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Sturanya fulgora (Gould, 1847) [Mousson 1869; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Sturanya musiva (Gould, 1847) [Mousson 1869; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Sturanya plicatilis (Mousson, 1865) [Mousson 1869; Cowie 1998; Cowie & Robinson 2003]

**Sturanya* sp. 1 [F. Brook pers. obs. 2012]

NEOCYCLOTIDAE

Ostodes exasperatus Girardi, 1978 [Girardi 1978; F. Brook pers. obs. 2012]

Ostodes garretti Clench, 1949 [Clench 1949; Girardi 1978; F. Brook pers. obs. 2012]

Ostodes gassiesi (Souverbie, 1859) [Girardi 1978; = *S. plicatus* record of Cowie & Robinson 2003]

Ostodes llanero Girardi, 1978 [Girardi 1978; F. Brook pers. obs. 2012]

Ostodes savaii Clench, 1949 [Clench 1949; Girardi 1978; F. Brook pers. obs. 2012]

Ostodes tiara (Gould, 1847) [Cowie & Robinson 2003]

Ostodes upolensis (Mousson, 1865) [Clench 1949; Girardi 1978]

DIPLOMMATINIDAE

Diplommatina problematica (Mousson, 1865) [Cowie & Robinson 2003]

TRUNCATELLIDAE

Truncatella guerinii Villa & Villa, 1841 [Mousson 1869; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

ASSIMINEIDAE

Assiminea parvula (Mousson, 1865) [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Omphalotropis bifilaris Mousson, 1865 [Cowie & Robinson 2003]

Omphalotropis biliratus Mousson, 1865 [Mousson 1869; Garrett 1887; Cowie & Robinson 2003]

Omphalotropis conoideus Mousson, 1865 [Mousson 1869; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

**Omphalotropis* sp. 1 [F. Brook pers. obs. 2012]

VERONICELLIDAE

****Laevicaulis alte*** **(Ferussac, 1822)** [F. Brook pers. obs. 2012]

Sarasinula plebeia **(Fischer, 1868)** [Cowie & Robinson 2003; Gomes & Thomé 2004; F. Brook pers. obs. 2012]

ELLOBIIDAE

Melampus fasciatus (Deshayes, 1830) [Mousson 1869; F. Brook pers. obs. 2012]

**Melampus luteus* (Quoy & Gaimard, 1832) [F. Brook pers. obs. 2012]

Pythia scarabaeus (Linnaeus, 1758) [Mousson 1869 – as *P. savaiensis*; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

ACHATINELLIDAE

***Lamellidea oblonga* (Pease, 1865)** [F. Brook pers. obs. 2012]

**Lamellidea pusilla* (Gould, 1847) [F. Brook pers. obs. 2012]

VERTIGINIDAE

***Gastrocopta pediculus* (Shuttleworth, 1852)** [F. Brook pers. obs. 2012]

***Gastrocopta servilis* (Gould, 1843)** [F. Brook pers. obs. 2012]

Nesopupa goddefroyi (Boettger, 1881) [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

***Pupisoma orcula* (Benson, 1850)** [F. Brook pers. obs. 2012]

PARTULIDAE

Eua expansa (Pease, 1871) [Kondo 1968; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Samoana canalis (Mousson, 1865) [Kondo 1968; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Samoana stevensoniana (Pilsbry, 1909) [Kondo 1968; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

SUBULINIDAE

***Allopeas gracile* (Hutton, 1834)** [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

***Allopeas micra* (d'Orbigny, 1835)** [F. Brook pers. obs. 2012]

***Opeas hannense* (Rang, 1831)** [F. Brook pers. obs. 2012]

***Paropeas achatinaceum* (Pfeiffer, 1846)** [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

***Subulina octona* (Bruguiere, 1789)** [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

ACHATINIDAE

***Achatina fulica* Bowdich, 1822** [Warren Joplin pers. comm.. 2012; F. Brook pers. obs. 2012]

RHYTIDIDAE

Delos gradata (Gould, 1846) [Cooke 1942; Kondo 1943; Cowie 1998; F. Brook pers. obs. 2012]

ENDODONTIDAE

**Thaumatodon hystricelloides* (Mousson, 1865) [F. Brook pers. obs. 2012]

CHAROPIDAE

*_Discocharopa aperta_ (Mollendorff, 1888) [F. Brook pers. obs. 2012]

Graeffedon savaiiensis Solem 1983 [Solem 1983]

Sinployea allecta (Cox, 1870) [Solem 1983; F. Brook pers. obs. 2012]

*_Sinployea_ sp. 1 [F. Brook pers. obs. 2012]

EUCONULIDAE

Diastole lamellaxis Baker, 1938 [Baker 1938; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012

Diastole savaii Baker, 1938 [Baker 1938; Cowie 1998; F. Brook pers. obs. 2012

Diastole schmeltziana var. _usurpata (Mousson, 1869) [Mousson 1869; Garrett 1887; Baker 1938; Cowie 1998; F. Brook pers. obs. 2012]_

*Kororia palaensis (Semper, 1870) [F. Brook pers. obs. 2012]

Lamprocystis perpolita (Mousson, 1869) [Baker 1938; Cowie 1998; F. Brook pers. obs. 2012]

Lamprocystis upolensis (Mousson, 1865) [Mousson 1869; Cowie 1998; F. Brook pers. obs. 2012]

Liardetia samoensis (Mousson, 1865) [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

*'Microcystina' gerritsi Benthem Jutting, 1964 [F. Brook pers. obs. 2012]

ARIOPHANTIDAE

*Parmarion martensi Simroth, 1893 [F. Brook pers. obs. 2012]

ZONITIDAE

Trochomorpha apia (Hombron & Jacquinot, 1852) [Baker 1941; Cowie 1998; Cowie & Robinson 2003]

Trochomorpha troilus var. _savaii_ Baker, 1941 [Baker 1941; Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

SUCCINEIDAE

Quickia concisa (Morelet, 1848) [Cowie & Robinson 2003 – as _Succinea modesta_; Brook 2010; F. Brook pers. obs. 2012]

Succinea putamen Gould, 1846 [Cowie & Robinson 2003; F. Brook pers. obs. 2012]

BRADYBAENIDAE

Bradybaena similaris (Rang, 1831) [Cowie 1998; Cowie & Robinson 2003; F. Brook pers. obs. 2012]

Figure 1. Location of historical landsnail collecting sites on Savai'i

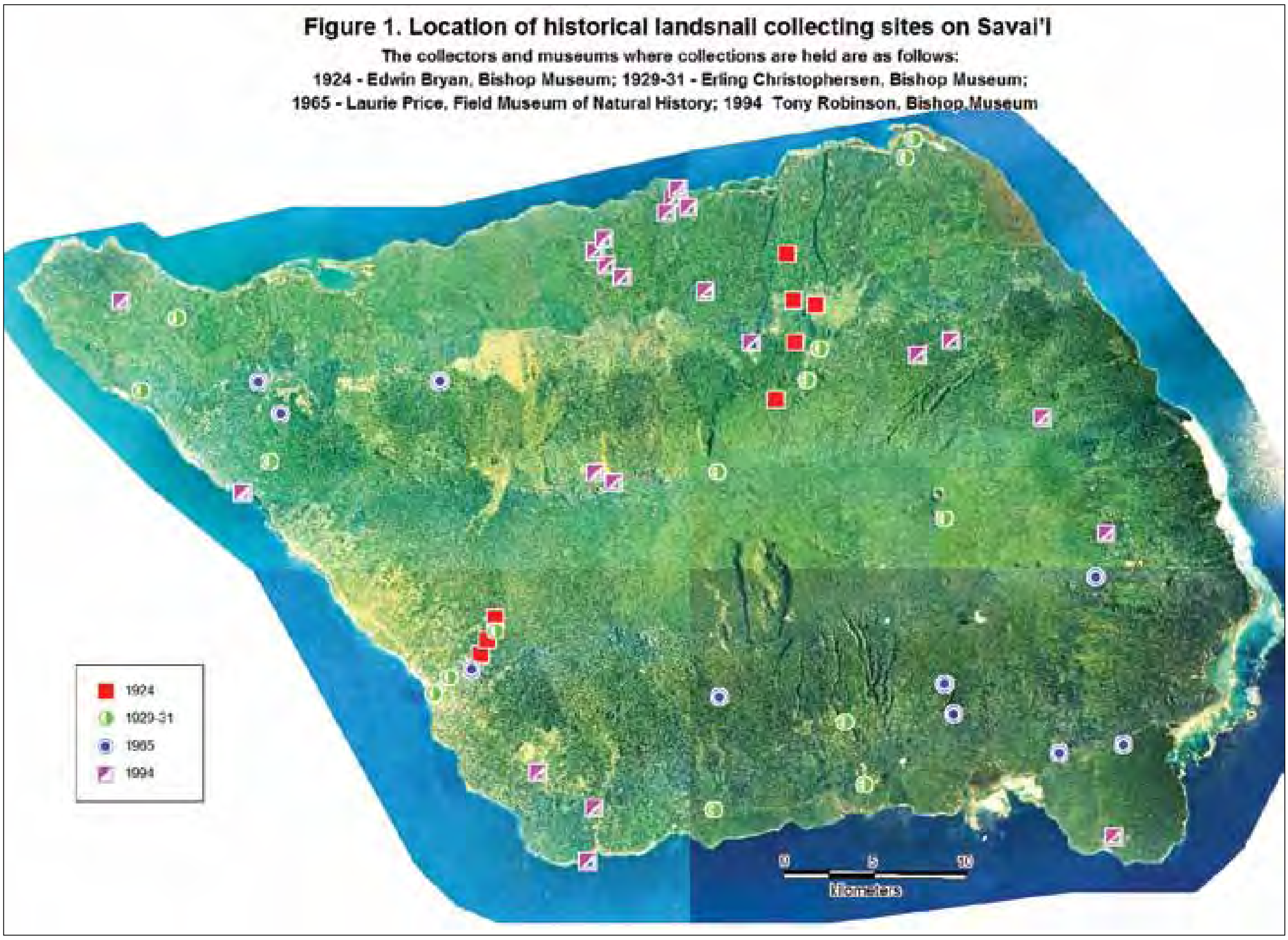
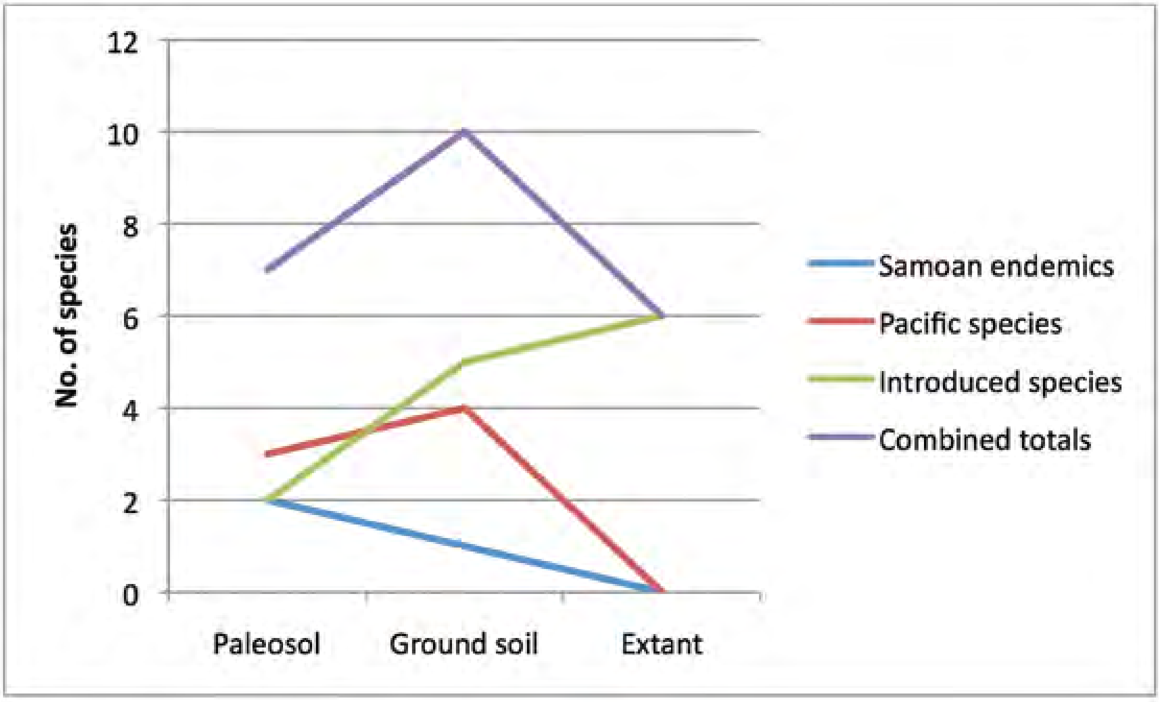


Figure 2. Biogeographic changes in landsnail assemblages in a coastal section near Salimu, Savai'i.



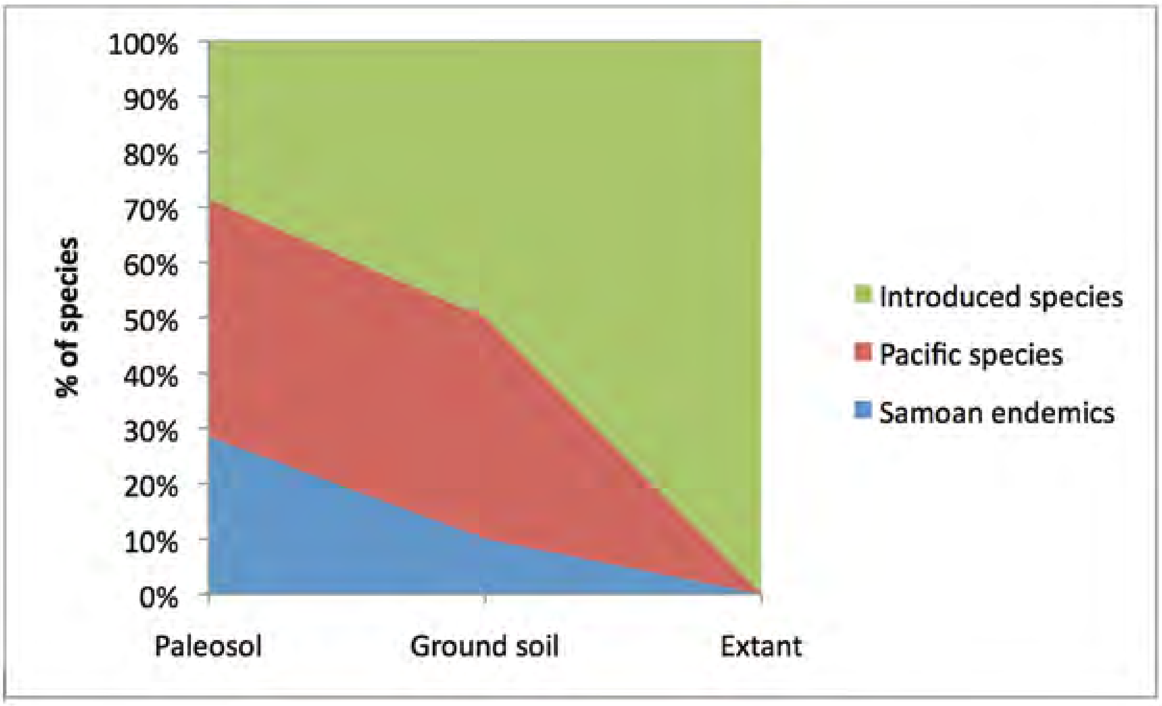
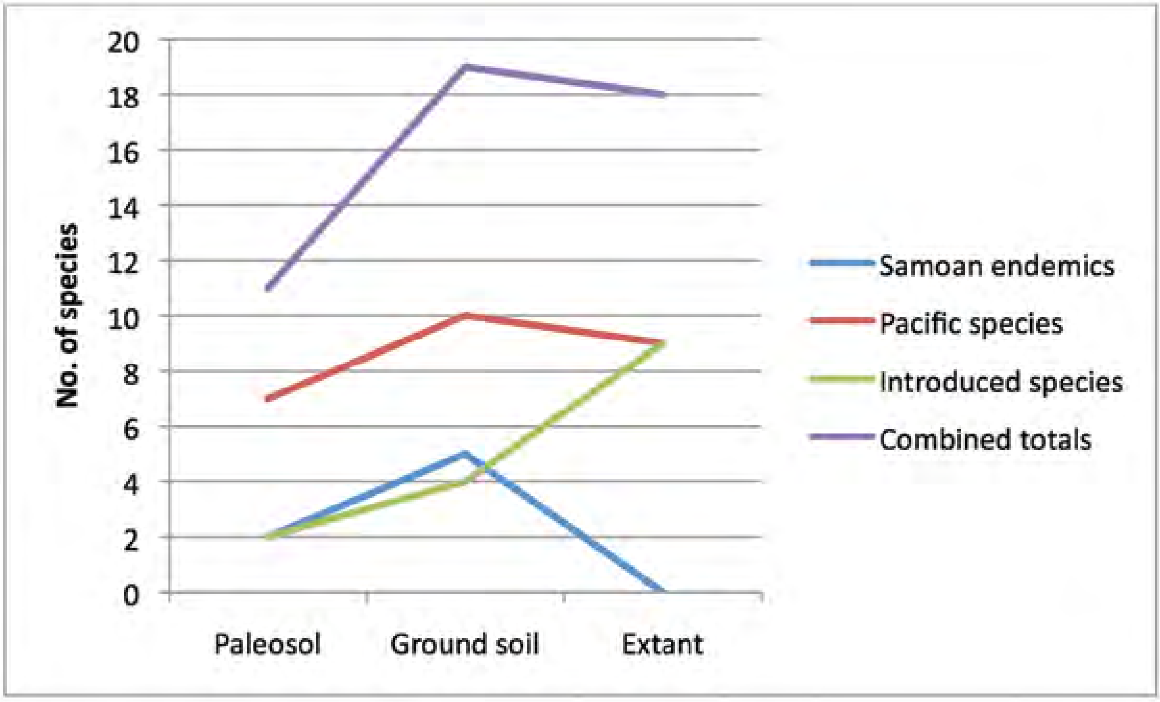


Figure 3. Biogeographic changes in landsnail assemblages in a coastal section at Aganoa Beach, Savai'i.



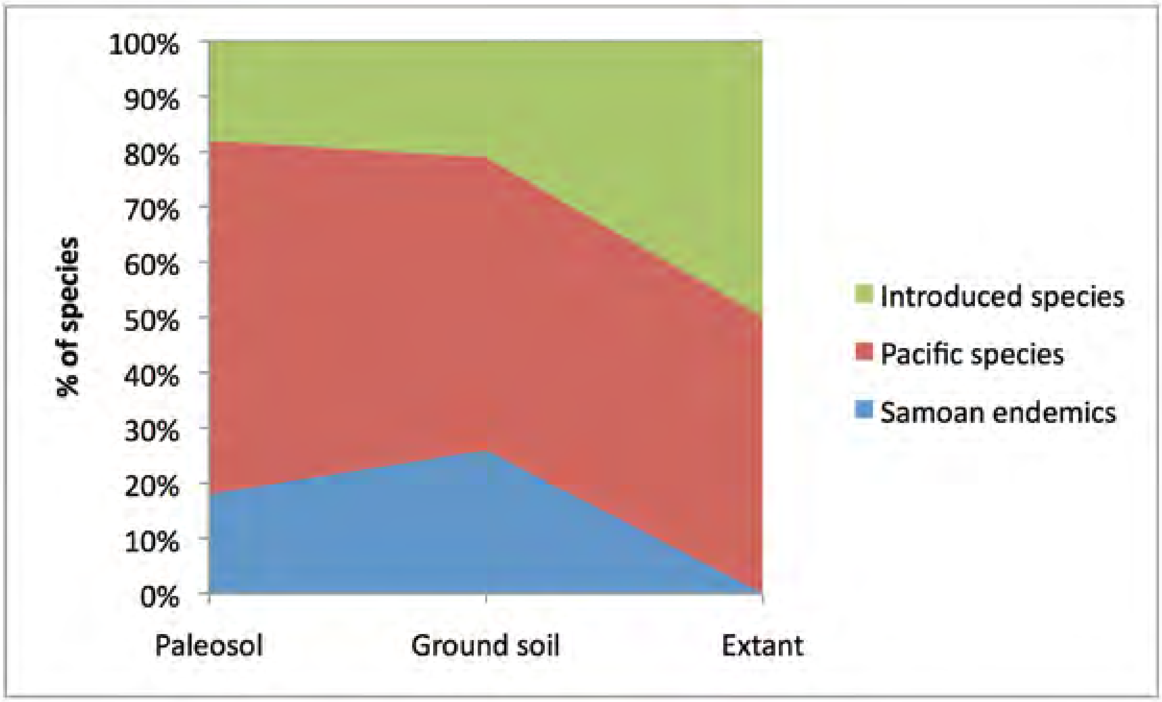


Figure 4. Biogeographic changes in landsnail assemblages in a coastal section near Cape Asuisui, Savai'i.

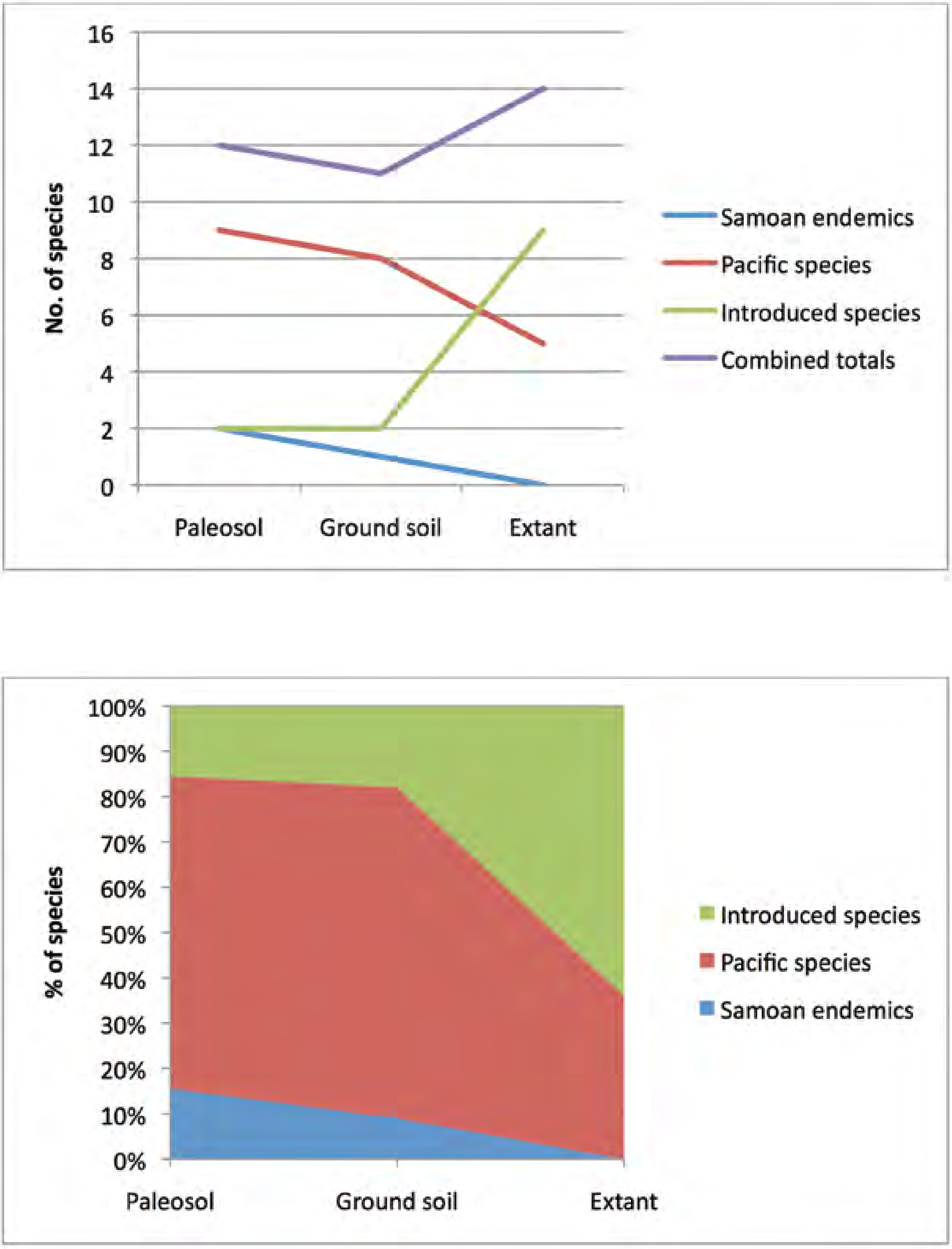


Figure 5. Biogeographic changes in landsnail assemblages in a coastal section near Tufutafoe, Savai'i.