THE TERRESTRIAL ECOLOGY AND BOTANY OF TOFUA AND KAO ISLANDS IN HA'APAI, KINGDOM OF TONGA

- a survey for biodiversity conservation

by

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and
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JULY 2001

THE TERRESTRIAL ECOLOGY AND BOTANY OF TOFUA AND KAO ISLANDS IN HA'APAI, KINGDOM OF TONGA

- a survey for biodiversity conservation

is

the report of the botanical survey of the Ha'apai Conservation Area Project, of the South Pacific Biodiversity Conservation Programme

compiled and written

by

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CONTENTS

Cover photo: The volcanic island of Kao viewed from beneath a ponga (*Cyathea lunulata*) in a fernland of kahiva'e (*Pteridium esculentum*) with toa trees (*Casuarina equisetifolia*) on the upper slopes of Tofua. The cloud cover on the summit of Kao is a regular feature, and with the altitude of the island (330m), creates a unique environment dominated by wet fernland.

All photographs : Geoff Park

EXECUTIVE SUMMARY

Ha'apai is what ecologists call a transformation landscape. The ecosystems of Ha'apai are the consequence of people manipulating the islands' plants and animals over thousands of years. Some of the species of plant and animal that occurred in Ha'apai before people arrived have survived. Many have become extinct.

Many of the native biodiversity assets of the Kingdom of Tonga's Ha'apai Group, notably primary forest and the myriad plants, birds and other animals that are dependent on forest habitat, are now confined to Tofua and Kao, the isolated, high volcanic islands to the west of the group. It is for this reason that the Ha'apai Conservation Area project has identified Tofua and Kao as priority areas for conserving biodiversity. This recognition of the importance of Tofua and Kao is a core component of the project's objective of involving local Ha'apai communities in promoting ecologically sustainable development in Ha'apai. This survey has been undertaken for Ha'apai to have up-to-date information on Tofua and Kao's biodiversity values in order to facilitate that objective.

The ecological and botanical studies that are undertaken for biodiversity conservation usually focus on the plants and animals and communities that have become rare and might become extinct unless action is taken to protect them. Like the protected areas that these studies propose, they commonly tend to ignore or overlook the relationship between the processes that have operated through history to create the landscapes that prevail in the small islands of the South Pacific today.

Biodiversity conservation, in the form of the Conservation Areas that the South Pacific Biodiversity Conservation Programme is establishing is essentially a matter of bringing the past into the present. This is particularly the case with the Ha'apai Conservation Area Project with its emphasis that biodiversity must include the knowledge, beliefs, customs and language of Ha'apai's people concerning its plants, animals and their ecosystems, as well as those plants, animals and ecosystems themselves. It is an expression of the generally poorly recognised life-link that the Tongan writer Epeli Hau'ofa calls the "very intimate association between history and the natural landscape":

> We cannot read our histories without knowing how to read our landscapes. When we realise this, we should be able to understand why our languages locate the past as ahead or in front of us. It is right there on our landscapes in front of our eyes. That is one reason why it is essential that we do not destroy our landmarks, for with their removal very important parts of our memories, our histories, will be erased. (Hau'ofa, 1994)

Historically, Tofua and Kao have been "resource islands" for Ha'apai people who have utilised them from other more-inhabited islands. This pattern of utilisation of Tofua and Kao's plants and animals could reach back to when people in canoes with plants and domesticated animals on board first arrived from the western ocean nearly 3000 years ago, and rapidly spread their settlements throughout Ha'apai's multitude of low islands. Ha'apai is believed to have been where human inhabitation of the Kingdom of Tonga first began.(Burley, 1998; Burley et al , 1999). Tofua and Kao's height above the ocean not only would have made them the most visible of Ha'apai's islands. From their heights, the first people could have seen Ha'apai's many inhabitable low islands.

The native biodiversity of the Ha'apais - the plants, animals and ecosystems that the first colonisers encountered - was undoubtedly a major early influence in shaping the islands' human cultures. But almost 3000 years of human settlement and cultivation have led to a situation in which very little of the Ha'apais' native biodiversity remains. Throughout the low islands of the Ha'pais, where almost all human settlement is now located, not even a small patch of the primary forests that once covered the islands has survived the combination of customary cultivation practices and the increased demand on land to produce food crops that came with Christianity in the 19th century. Today, primary forest exists only on Tofua and Kao. For this reason, it is believed, the abundance and species richness of land birds is now much greater on Tofua than on the other Ha'apai islands.

The Ha'apai Conservation Area Project is recognition that the provision of some form of protection for the native biodiversity of the Ha'apais is more pressing than it has ever been. If the people of the Ha'apais are to retain the precious biodiversity resources that derive from the ancient primary forest ecosystem, or are dependent on it, it is to Tofua and Kao to which they must turn.

Ornithologists have recently identified Tofua as 'an essential island' for conserving populations of Ha'apai's land birds.(Steadman, 1998) On the other hand, while Tofua and Kao may be barely inhabited these days, they, Tofua in particular, are crucial 'resource islands' for human communities elsewhere in the Ha'apais, chiefly Kotu in the western Lulunga district, and have been so for a very long time historically. The Ha'apai Conservation Area project's plans for a Conservation Area on Tofua and Kao needs to have regard for both these values.

This study surveys Tofua and Kao's terrestrial plant communities. It reports on an expedition to the two islands in July, 1997 in which 11 days were spent on Tofua and 3 days on Kao. Given the large area and difficult terrain of both islands and the very limited time for the botanical survey, the primary objective was determining the range of the islands' major plant communities and recording samples of them in order that they could be described and mapped, and their condition and conservation status assessed. Paralleling this, the survey endeavoured to compile as comprehensive record as possible of the islands' vascular plant species. It was not possible to cover all of the islands' environments. Large areas of southern Tofua and much of Kao were not encountered on the ground, but surveyed from the sea.

This report is primarily a descriptive account of the plants and plant communities of Tofua and Kao in the context of biodiversity conservation. An account of the islands' geology is included because Tofua and Kao's active volcanic character is a major influence on their biodiversity. Unfortunately howevere, the survey of introduced plants species that was integral to the botanical survey was not paralleled by a survey of introduced animal species, the management of which will be important in future biodiversity conservation.

Because of the significance of Tofua's primary forests for biodiversity conservation, the expedition made them the primary focus of limited time on the two islands. This report describes the forests' composition and structure and maps their extent together with other plant communities. It looks in particular at the land use practices that currently impact on

the primary forests, or could do so in future. The land uses with greatest potential impact on biodiversity values are *kavu* cultivation, the use of fire for land clearance, and the feral browsing (goats) and predator animals (notably dogs) that have reached Tofua and Kao with human settlement.

Because the Ha'apai Conservation Area Project is community-based, the report also touches on land tenure on Tofua and Kao and on the islands' economic significance as resource islands, notably the particularly important relationship between Tofua and Kotu in the Lulunga district of Ha'apai. On the basis of these field surveys and assessments, and these factors of geology and land tenure, the study presents a series of recommendations for biodiversity conservation.

* * *

1. Geographic Introduction

Tonga, which lies at a latitude of 15--23° south and a longitude of 173--177° west, comprises about 150 islands with a total area of 697 km^2, but only about 36 of these islands are currently inhabited. The archipelago is basically a double chain of islands running in a north-northeast direction with small, high, volcanically active islands on the west, and lower, larger raised coral islands on the east. The main limestone islands are Tongatapu (257 km^2 in area, 80 m elevation), 'Eua (87 km^2, 330 m), and Vava'u (90 km^2, 200 m).

Numerous, small, raised-coralline islands known collectively as Ha'apai lie between Tongatapu and Vava'u (Fig.1) In the volcanic chain, the main islands of the southern part, going from south to north, are 'Ata, Tofua, Kao, Late, and Fonualei; of these, only Tofua is inhabited. Kao, which lies adjacent to Tofua, has the highest elevation in Tonga (1046 m). The northern part of the volcanic chain comprises three islands, Niuafo'ou, Niuatoputapu, and Tafahi, all of which are inhabited. The present study includes only the volcanic islands of Kao and Tofua.

Since Tonga is situated between the Tropic of Capricorn and the Equator, its climate is tropical. There is little seasonal or diurnal temperature variation, although the winters are sometimes relatively cool. There is no pronounced dry season and all areas except Ha'apai

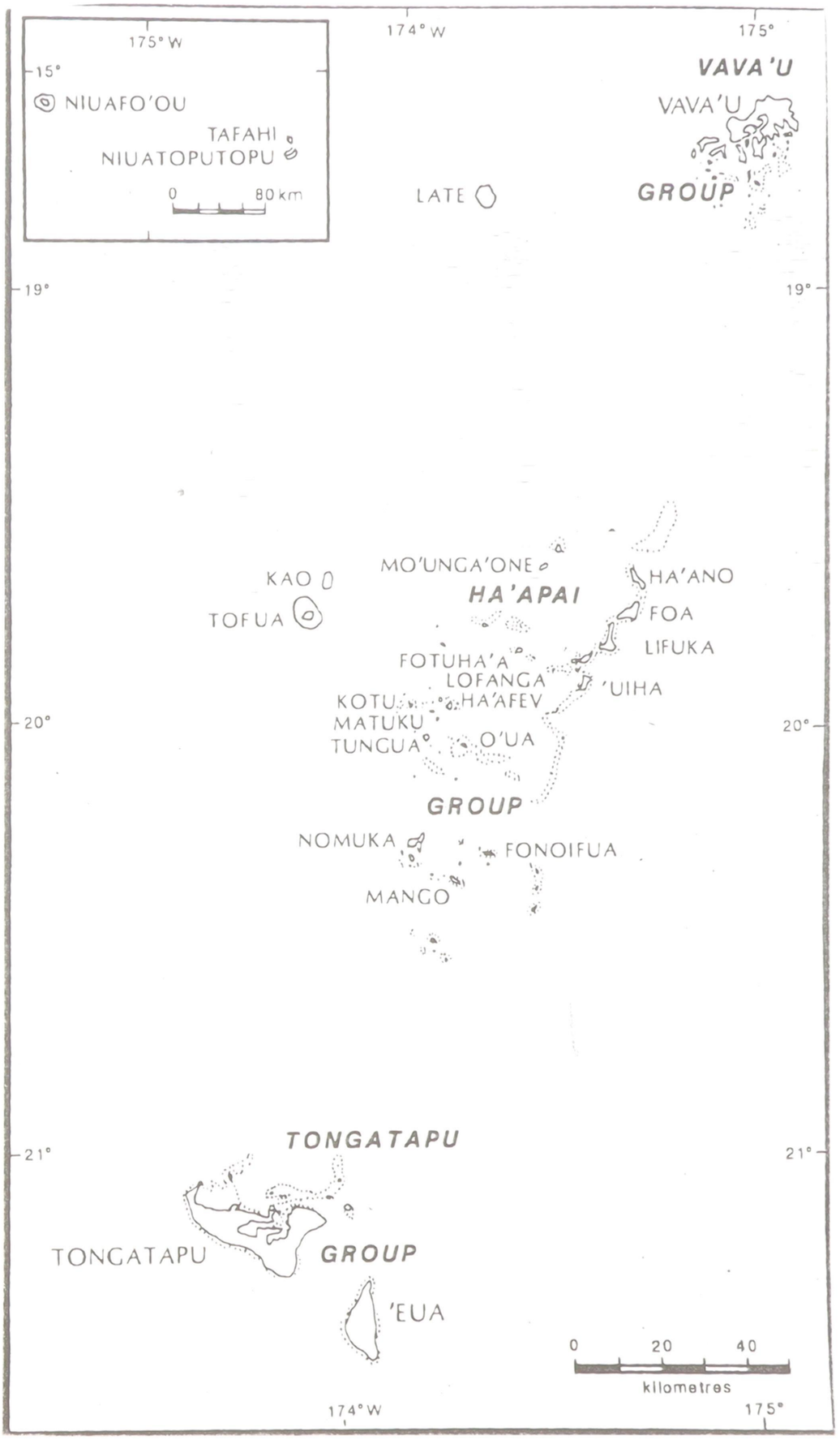

Figure 1. The Kingdom of Tonga, showing Tofua and Kao in the western Ha'apai Group.

receive at least 200 cm of annual precipitation. Occasional droughts, however, may occur, and hurricanes are a threat in the summer season (January to April).

The islands of the archipelago are mostly coralline and "continental," and lie on the eastern edge of the Asia-Australia Plate. Uplifting of the edge of this plate, caused by subduction of the Pacific Plate under it, has resulted in volcanic activity that created the western chain of volcanic islands. Ash from an ancient volcanic eruption in that chain now covers most of the coralline surface of the rest of the archipelago. Volcanic activity continues today in the western chain -- on Tofua, which is steaming, and on subsurface volcanoes that are forming new islands.

The area of study, Kao and Tofua, is located in the Ha'apai Islands in the volcanic, western chain of islands, about 24 km northwest (Tofua) of the nearest coralline Ha'apai island, Kotu, just to the northwest of the intersection of 20°S and 175° W. Tofua, the larger of the two islands, has an area of 46.6 km^2 and a maximum elevation of 506 m, while Kao, lying to the north across a strait 6 km wide, has an area of 12.5 km2 and a maximum elevation of 1046m (Bauer, 1970; Crane,1992). Tofua is currently volcanically active, with a fumerole inside the main crater. Its last significant eruption was in 1959. Kao is dormant or extinct, with no historical record of eruption.

2. The Background and Context of the Ecological and Botanical Survey

This ecological survey of Tofua and Kao derives from the Kingdom of Tonga's initiative to designate the entire Ha'apai island group as a Conservation Area under the South Pacific Biodiversity Conservation Programme (SPBCP) of the South Pacific Regional Environmental Programme, and to select 'priority islands and priority communities' for action within it; Tofua and Kao being such islands.

That initiative, in turn, derives from the actively representation of Pacific Island governments at the "Earth Summit", the United Nations Conference on Environment and Development (UNCED) in Rio Janeiro, in 1992. Nine Pacific island countries' signed the UNCED global Convention on Biological Diversity (CBD).

The CBD's signing has brought increasing recognition in the region of the importance of biodiversity conservation as a basis for sustainable development. Most significantly, it has focused worldwide attention on a particular concern in the Pacific; the establishing and resourcing of conservation management programmes in small island ecosystems with "globally significant areas of biological diversity" such as Tofua and Kao, and people, such as those of Ha'apai, whose traditional cultures and subsistence economies depend in them.

The SPBCP's implementation of the Convention in the South Pacific is being facilitated by the South Pacific Regional Environment Programme (SPREP). The SPBCP's five-year programme is made possible by the Global Environmental Facility (GEF) and the

Government of Australia. The GEF is administered by the World Bank, the United Nations Environment Programme and the United Nations Development Programme.

The South Pacific Biodiversity Conservation Programme's main emphasis is establishing a Pacific-wide series of diverse Conservation Areas (CAs) encompassing globally significant areas of biodiversity in which the local community is made aware of the special plants, animals and ecosystems some of their islands contain and the values the wider world attaches to them, and human activities are guided to protect them and, if using them, doing so sustainably.

The SPBCP's Conservation Area philosophy is that Conservation Areas must reflect the wishes and desires of the local people. While a CA is formally proposed by a Pacific Island Government or organisation - as the Kingdom of Tonga has proposed the Ha'apai Conservation Area - the local communities living within the CA effectively own and operate it. These local communities are an integral part of the project initiation process that selects the priority areas within the CA for the conservation of biological diversity, and ultimately, they will take over the CA's administration and management of sustainable development beyond the funding period of the SPBCP.

The SCBCP stipulates that the initial phase of Conservation Area Projects should focus on two or three priority islands or pilot communities. The Programme's User Guidelines for participating Pacific nations sets out criteria concentrate for the selection of priority Conservation Areas. In the case of Ha'apai:

1. The islands should have a wide range of terrestrial and marine ecosystems and biodiversity which are representative of the Ha'apai group as a whole;

2. The islands should have a wide range of current and potential commercial and subsistence economic alternatives/activities which are representative of the Ha'apai Group.

3. The islands should have terrestrial and marine species or genotypes that are endangered within the Ha'apai group, or nationally, or which have particular cultural or economic value to the people of Ha'apai and Tonga.

4. The island ecosystems and biodiversity could be threatened by over-exploitation, degradation or conversion to non-sustainable uses

5. The island communities (resource users) and their representatives must give a clear commitment to participatory involvement in the planning, implementation, monitoring, modification and expansion of the project.

6. The location of the islands could optimise the possibility of the success of the implementation, monitoring and modification of Phase I of the project in terms of logistics, cost and time constraints and the desire for the spread of the benefits of the project to other areas of Ha'apai and Tonga.

Tofua and Kao, and their respective communities, were selected as priority islands for the following reasons:

1. They are classic recent andesitic volcanoes of considerable international scientific and tourist importance.

2. They have a unique and relatively undisturbed indigenous flora and fauna, and thus could constitute national and international natural heritage sites.

3. They constitute resource islands, the terrestrial and marine resources of which could be exploited on a sustainable basis if managed properly. This includes a turtle nesting site on Tofua.

4. They are both the increasing focus of unplanned exploitation of their terrestrial and marine resources.

5. There are reports that the deep waters, relatively close to islands, have demonstrated high catch rates for tuna and other large pelagic fish species and offer substantial potential for fisheries development.

An important parallel principle in the choice of priority islands was that sustainable resource management was a feasible goal in that there was a high level of commitment to it within the local community. The SPBCP places considerable importance on the Conservation Area model developing from community-based participation in developing appropriate local mechanisms for biodiversity conservation and sustainable management in the island Pacific In that regard, the SPBCP requires the choice of likely conservation areas within the wider project area to be coherent not only in ecological terms, but also in terms of land tenure; that is, that land involved be that held customarily by that particular local community (SPREP/UNDP/GEF, 1993).

The present ecological survey was undertaken as part of the participatory planning component of the Ha'apai Conservation Area (HCA) Project, through which the Ha'apai community identifies what its particular pattern of islands needs in order to integrate biodiversity conservation into sustainable resource management. Central to that process are:

1. Identification of endangered or culturally and economically important ecosystems and plant and animal species within the HCA, and that could become the focus of community-level protection and sustainable management activities.

2. Identification of activities and resource-use strategies which constitute serious constraints to conservation and the sustainable use of biodiversity within the HCA.

3. Identification by local communities, both individually and collectively, of activities which offer the most promise for promoting the sustainable use of biodiversity to improve cash and non-cash incomes and the quality of life.

4. Identification and prioritisation of activities, at the community, regional and national levels, which could promote the sustainable use of biodiversity and eliminate or minimise unsustainable activities in the HCA. (HCA Project Preparation Document, 1995)

This survey was to facilitate those objectives by providing an authoritative scientific account of the plants and plant communities of Tofua and Kao and the current impact of human activities on them, and recommendations for their conservation and sustainable management.

3. The Physical Setting of Tofua and Kao, within Ha'apai and wider Tonga.

When people on Ha'apai's low sand cays and raised limestone islands describe the two volcanoes visible on their western horizon as wild, dangerous islands, difficult to access and inhabit, what they are saying, in effect, is that it is Tofua and Kao's physical character that makes them so important to biodiversity conservation in this part of the Pacific at the end of the 20th century. This physical character, so very different to the rest of Ha'apai's islands, severely constrains human settlement.

Tofua and Kao are both islands that physically restrict human activity, whether it be cultivating crops, gathering plant material, hunting, or undertaking biodiversity surveys. Even though this expedition for the Ha'apai Conservation Area project was on the islands for almost three weeks, large sectors were not examined in close detail simply because of the difficulty of traversing some parts of Tofua and Kao. This physical constraint on human access, along with the constant threat of volcanic eruption (sufficiently great last century to cause Tofua to be evacuated), the scarcity of permanent freshwater on their steep slopes, and the lack of a protective fringing reef and beach formation, has served historically to severely limit human settlement. The effect has been to preserve primary forest in an archipelago in which human activity has otherwise almost completely removed it.

3.1 The Islands' Active Volcanism and its Influence on their Biodiversity.

Aside from human-lit fires getting away from land clearance burn-offs, fire from future eruptions is likely to be the greatest threat to the continued survival of the Tofua and Kao's forests. Volcanism has the potential to eliminate the biodiversity of both the islands that the Ha'apai Conservation Area Project has identified as indigenous biodiversity resource areas. Because Ha'apai's primary forest resource is now confined to Tofua and Kao, the effect of a new massive eruption today on Ha'apai's biodiversity would therefore be enormous. This fact needs to be understood, recognised and allowed for in the Ha'apai Conservation Area's sustainable resource planning.

Tofua and Kao contain some of Tonga's very best rainforest ecosystems. Botanically they are part of the Fiji-West Polynesia extension of the Indo-Malayan rainforest formation, but they contain only a small portion of its plant species. Tofua and Kao's forests are depauperate ecosystems in indigenous biodiversity terms,[3] with virtually no endemic[4] species

[3] "Depauperate in indigenous biodiversity terms" means relatively poor in the number of native plants and animals compared to other land areas.

[4] Endemic means found only in this locality and nowhere else on earth.

despite their long isolation. That they are so is attributable to their land surface being subject to violent eruptions and at a great distance from other forested islands.

So massive have some of Tofua's eruptions been that islands 60km distant have been progressively covered with over 2 metres of airfall ash. As was the case with the Indonesian island Krakatoa in 1883, eruptions of this scale tend to eliminate virtually all life, which over the next century or two, then recolonises the new ground - as long as the seed sources and disperser species still survive elsewhere in the region. Beyond Tofua and Kao, Ha'apai no longer has any surviving areas of primary forest habitat. Thus the future existence of any primary forest plant or animal species that were once widespread throughout Ha'apai but is now confined to Tofua and Kao, have to be considered precarious long-term, unless steps are taken to provide suitable habitat for the species or forest elsewhere in Ha'apai.

Tofua and Kao are two of five volcanic outliers in the western part of the Ha'apai group of islands, the others being Hunga Ha'apai, Hunga Tonga and Falcon. They are the surface expressions of a volcanically active submarine ridge parallel to, and separated from another, eastern ridge on which 57 raised limestone islands or sand cays are situated.

Kao, at 1046m, by far the highest island in Tonga (**Fig 2**), and high enough for the uppermost 300m or so to be regularly obscured by cloud cover. It is a dormant stratovolcano composed of basaltic andesite lavas with some airfall materials. Kao is approximately 5 km long by 3.3 km wide, and lightly dissected with well incised drainages, mainly on the northwest side. It has a central crater, with some dormant cones within.

Tofua (**Fig. 3**) lies approximately 4km to the south of Kao. At 46.6 km^2, the largest island in Ha'apai, it is an andesite strato-volcano with a large central crater lake and a history of violent eruptions (Leaman *et al*, 1988). It is circular in shape, approximately 8 km across, and still sufficiently active to have a pronounced influence on the island's vegetation, notably on lava fields and ash plains within the large explosion crater, and on upper slopes leeward of the prevailing southeast trade-winds. Tofua's dynamic volcanic character is reflected in its steep, broad and lightly dissected slopes, its rocky, cliffed coastline and the paucity of sandy beaches.

As active volcanoes, Tofua and Kao are *young* islands; younger than any of their plants and animals are evolutionarily. No plant or animal, in other words, has *evolved* there. Every plant or animal species occurring on Tofua and Kao has got there, somehow, from some other nearby land-mass, established itself, spread and somehow survived local eruptions. Only a few (four of twelve) of Tonga's endemic species occur on Tofua and Kao. Only one species (*Selaginella yunckeri*) is apparently endemic, and that must have reached there in earlier times from an ancient land-mass that no longer exists.

Tofua's geology is considered to be complex. The ground surfaces on which vegetation development has proceeded is made up of four main parent material types:

- interlayered lavas and pyroclastics
- ash and pumice flows
- ignimbrite and pumice breccia flows
- massive lava flows.

Figure 2. Kao, the highest island in the Kingdom of Tonga, seen from Tofua. The nearest lower slopes of Kao have been cleared for plantations.

Figure 3. Tofua viewed from the upper slopes of Kao. The front (north and eastern) slopes of Tofua are in a mosaic of toafa fernland and secondary scrub and forest. This pattern is maintained by occasional deliberate burning; the most recent fire is clearly visible. Large areas of forest are concentrated within the crater, of which the most recent volcanic vent can be seen in continuous eruption. [Photo: Geoff Park, August 1997]

Each of these can produce a very different ground surface, each responds differently and at different rates to the myriad processes of soil and vegetation development on new volcanic surfaces. For example, the much of the north-east quadrant of Tofua is formed from lava flows 2-4 m in thickness, interlayered with scoriaceous breccia and airfall lapilli tuffs (**Fig. 4**). The southern half of the island, in contrast, is formed mainly from ash and pumice deposits, that on the coast form spectacular cliffs up to 80m high. These differences are likely to be influential in the development of different forest types, but further work, beyond the scope of the present survey, would be necessary to establish it.

Tofua and Kao are both distinguished by an almost inaccessible coastline of massive cliffs; the result of the combination of:

- the prevailingly steep slopes deriving from the steep angle-of-rest of the andesitic parent material,
- the sensitivity of their volcanic parent materials to marine erosion,
- the geological youth of the island volcanoes and the consequent lack of fringing reefs.

Tofua's largely inaccessible coastline of cliffs (**Fig. 5**) is a consequence of the progressive *interlayering* of lavas with pyroclastics, ash, pumice breccia and ignimbrite. From the sea, lavas 8-10m thick are frequently seen to overlap older and more-erodible non-lava materials as they have spilled down the slope and poured over previous cliffs. Not all lavas have originated from the central crater. the in a. Many appear to have flowed from fissures and vents on the volcanoes' outer flanks.

Tofua's general form, and the explosion crater which occupies about half of its area, suggest that its early volcanic history involved the development of a simple, centrally erupting stratovolcanic cone, similar to Kao today, but much larger. Precipitously steep cliffs, from the crater lake, which is near sea-level, to the crater rim at about 500m attest to the scale and force of past Tofua's past eruptions; massive enough to have covered the rest of Ha'apai's islands, 50km or more distant, with 2 metres or more of fine soil-forming tephra. Massive enough too, in some events, to have totally eliminated all plants and animals.

The lava flows that dominate Tofua'a coastline are possible remnants of the early development of the original volcano, as distinct to the lava flows within the crater that are more recent; after the removal of the top of the volcano. Following this removal, and ponding of lava in the central crater, large scale explosive eruptions, considered by geologists to have been "extremely energetic", continued from somewhere beneath the present crater lake. The next stage of volcanism was again explosive, and directed towards the south. By this stage , the present crater had been formed. Some of these explosive eruptions could well have occurred within the period of human inhabitation of Ha'apai, ie. the last 3000 years.

Projection of the flanks of the volcano suggests that prior to these later eruptions, the volcano may have reached to a height of between 1,800 and 2,000 metres. If this interpretation of geologists is correct, as the dominantly pyroclastic nature of its later eruptions suggests it is, volcanic ash of the order of 15 to 20 cubic kilometres has been removed by eruption.

Figure 4. The predominantly cliffed coast of Tofua (the northwestern side)

Figure 5. The pattern of volcanic activity and vegetation within the western part of the Tofua crater. Toafa (*Dicranopteris*) fernland dominates the foreground and the wooded vegetation is mainly toa (*Casuarina*).

Tofua's volcano and its violent history has ensured it a profound place in Tongan myth and tradition as the ancient god Lofia. Similarly, the fearful certainty, but unpredictability, of its erupting is considered to have been the key factor, historically, in the human use of Tofua as a resource island; always being complemented by access to some other island territory[5] (Perminow, 1993). Tofua was evacuated to Kotu in 1854 because of imminent eruption(West, 1865) The fact that the people who live on Kotu today have no apparent recollection of that eruption suggests that people were used to moving between Kotu and Tofua, for each island's different resources(Perminow, 1993). Tofua's continuous volcanic activity in historic times meant that the 'evacuation' of Tofua did not constitute the major social upheaval that has been the case with other Tongan volcanic islands like Nuiafo'ou. Tofua's reputation in Tongan culture as a place to be feared likely derives from ash and lava eruptions over the longer historical time frame of Ha'apai's 3000 years of human inhabitation, during which Tofua and Lofia have taken many human lives.

Early European accounts speak of sudden flames that 'continually shoot up from its smoking crater, and terrific eruptions [that] have from time to time taken place, accompanied with showers of stones and streams of molten lava' (Angas, 1866). Tofua was recorded as being in eruption during James Cook's second voyage to the Pacific in 1774. 14 years later, William Bligh and those with him in the *Bounty*'s launch used the volcano's night glow to navigate in the wake of the Mutiny. As well as being active enough in 1854 for the island to evacuated, Tofua was slightly active in 1885, but quiet until three eruptions in 1906, and then again in 1926.

In recent years, Tofua has been continuously active at a low level, its eruptions of both lava and ash having a major influence on the present-day pattern of plant communities, especially within the crater rim. Within the crater, itself evidence of the very massive scale of some of Tofua's past eruptions (**Fig. 6**), a complexity of plant communities is evidence that the more recent eruptions have directly affected only *part* of the crater area. This should not be interpreted as evidence that Tofua is becoming progressively inactive. All it means is that the age-range of plant communities within the crater, from bare lava with only a few initial colonising plants (**Fig. 7**), to a mature, multi-layered and large-tree rainforest (**Fig. 8**), is suggestive of a high frequency of eruptions sufficiently large to have locally eliminated forest vegetation over the last 200 years or more.

Outside the crater rim, there are many plant communities such as secondary forest of tavahi (*Rhus taitensis*), toi (*Alphitonia zizyphoides*)and afa (*Neoaudea foreteri*), and toa (*Casuarina*) woodland forest, that closely resemble the vegetation that develops on new volcanic surfaces prior to the full rainforest stage, but in most instances this is more likely attributable to fires getting away from fires lit to remove forest for cultivation or simply to open up scrub vegetation for human access. Some of these fires have spread to just inside the crater rim, but otherwise, no evidence whatsoever was found of human activity such as cultivation within the crater; the variety of vegetation types occurring there being entirely the consequence of Tofua'a recent volcanic activity.

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[5] Arne Perminow, University of Oslo, Norway, *pers comm.*, March 1998;
see also Pernimow's "The Big Lagoon: The Microeconomy of Kotu Island in the Kingdom of Tonga", *Pacific Viewpoint* 34 (2): 179-192, 1993.

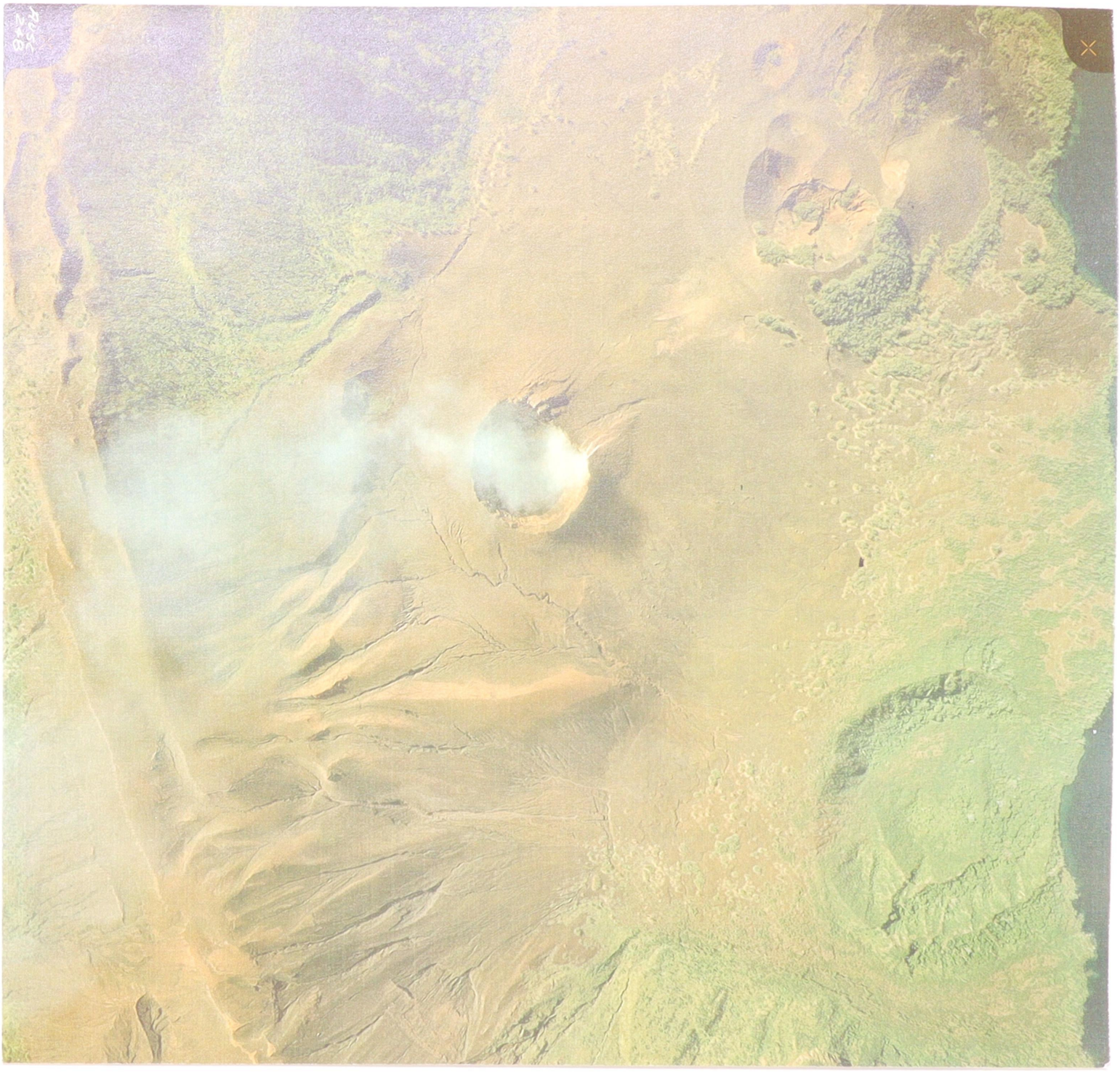

Figure 6. Aerial photograph of the western crater area of Tofua showing volcanic features, including the crater lake in the right margin. The effect of volcanic gases on halting vegetation development leeward of the current eruptive events is evident. The great majority of the darker green vegetation is dominated by toa (*Casuarina*), in different stages.

Figure 7. Toa (*Casuarina*) actively colonising lava flows within the Tofua crater, with older toa dominated forest in the foreground.

Figure 8. Primary rainforest dominated by tamanu and makai developed on older lava flows within the Tofua crater.

The most recent eruptions of both airfall pyroclastic deposits (ash) and lava have occurred from the two northern cones in the central crater (**Fig. 6**). One of these cones was continuously and noisily erupting steam throughout the duration of the 1997 Ha'apai Conservation Area Project expedition. Probable similar but older activity has also occurred from two nested cinder cones in the same area within the crater.

The recent pyroclastic deposits have spread widely around the area of the two northern cones and across the topographic rim of the main crater to the downwind, northwest side. They have destroyed whatever vegetation was in place at the time, and are spectacularly exposed along this sector of the crater rim (**Figs. 9 & 10**).

While the very existence, the sheer scale and steep inner cliffs of the crater suggests massive and extremely violent eruptions in the last 1000 years or so, of a scale that eliminated all plant-growth within the crater, the ecological diversity of the vegetation within it suggests that for the last 250 years or more, Tofua's eruptions have been much smaller and localised. Whatever the eruption type, some vegetation has persisted.

Much of the northern third of the main crater is comprised of lava flows that, by comparison with flows of known age on other islands, are estimated to be between 50 and 100 years in age (Leaman *et al*,1988). Some of these lava flows have flowed down to the crater lake from the two main northern cones, and been extensively covered with ash except towards the eastern end. Similar lavas have erupted from a fissure inside the south-east quadrant of the crater and have flowed down a sloping ledge of the older volcanics and, in some cases, spilled into the crater lake. The younger of these lavas are very recent, their broken *aa*[6] surface scarcely supporting any plant growth. An older, ash-covered lava in the same vicinity is being actively colonised by toa (*Casuarina*) woodland, which will succeed to rainforest if time allows. The oldest of the lavas, also ash-covered, forms a large gentle sloping surface which has eroded back to steep cliffs and bluffs where it meets the lake. This flow has been colonised by plants long enough for a substantial, mature rainforest community to have developed through toa woodlands (**Fig. 26**). A few surviving toa trees would suggest that the succession to rainforest has only recently occurred. But the massive stature of some of the makai and tamanu trees in what is one of the most impressive of Tofua and Kao's forests, indicate that the forest has been in place for the order of 100 years or more, and that whatever explosive eruptions have occurred in that period, they have not been large enough to destroy forest within the crater zone.

Some volcanic activity however has removed forest vegetation within the crater. The immediate proximity, in a few places, of mature rainforest to recent lava on which plant colonisation has barely begun, suggests that lava flowed through and incinerated similar forest. Vegetation re-development is minimal on the exposed lava surfaces, but where they are ash covered, toa woodlands have begun developing.

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[6] *Aa* is the Hawai'ian name for rough, broken lava; *pohuehue* for the smoother kind.

Figures 9 and 10. Recently erupted pyroclastic deposits on the western rim of the main Tofua crater.

4. The Ecological and Botanical Survey Project

4.1 The Survey Program

The field survey of Tofua and Kao in July 1997 was undertaken in order to have accurate, up-to-date information for biodiversity conservation programs, specifically the Ha'apai Conservation Area Project. The field survey had four primary objectives:

- to sample the islands' range of plant communities in order to record all vascular plant species occurring.
- to describe, sample and map the current extent of each plant community, notably the indigenous forests.
- to provide information on the present-day pattern of plant communities in a form that enables the Ha'apai Conservation Area Project to have an accurate base and suitable indicators for monitoring vegetation changes in future.
- to determine important plant communities under threat from human activities, in order to provide informed advice on future management options.

4.2 The Project Team

The survey team comprised scientists Dr. Geoff Park, Dr. Art Whistler, James Atherton, and Michael Hortle, the Ha'apai Conservation Area Project coordinator Sione Faka'osi of Pangai, Lifuka, Ha'apai; the forester Sunia Napa'a and botanist Manu Poumelile from Tongatapu, supported and guided in the field, cooked for, and very successfully fished for by Tiki Finau, Siua Hoko, Tevita Mafi, Viliami Fakahua, Lea Loni and Siaki Hoko of Lifuka, Ha'apai.

4.3 Survey Methodology and Coverage

Kao and Tofua were visited from Pangai, Lifuka from 7--20 July 1997. The first nine days were spent on Tofua, where the team made camp in and around the schoolhouse at the abandoned village of Hokula on the north side of the island. The last two days were spent on the south coast of Kao, where a camp was set up near the shore (there are no villages or inhabitants on Kao).

The very limited time on Tofua and Kao, their large size, very difficult access from all but a few landing-points, and their steep, arduous terrain, meant that neither island could be comprehensively covered. visited in on the islands. Given these limitations and the recognition early in the project that Tofua and Kao's primary forests were the main biodiversity asset on which the team needed to focus, the eleven days for the botanical survey were concentrated on determining the extent of primary forest and reaching the range of forest communities and habitats.

The objective of the botanical survey was to provide a sufficient sampling of the range of forest and associated vegetation types to provide a reliable base from which vegetation could

be mapped and the distribution of each major vegetation type extrapolated. Areas to survey were determined from aerial photos and reconnaissance. Each day the project team sought out and surveyed new areas of forest. In each area the vegetation was sampled to determine the relative composition of the vegetation and assign it to a vegetation type. Ground coverage was complemented by photography of all slopes of both islands from sea level during a circuit of Tofua and Kao specifically for this purpose by boat.

Throughout the botanical survey, a comprehensive checklist of the flora was compiled. However because of the impracticality of visiting all of Tofua and Kao's environments, the information gathered on the islands' vegetation types and the nature and extent of human impact upon them, is necessarily of a general overview rather than comprehensive.

During the vegetation study, six plots were sampled on Kao and Tofua, a time-consuming process deemed necessary for the understanding of the structure and composition of the forests. The data for these plots can be found in Table 5 in Appendix 2. Two more plots were sampled on Kao, but the quantitative data from these were not included in the report since the surveys were not supervised by the co-author (who was surveying the upper slopes of Kao at the time) and some of the data appeared to be inaccurate (some of the less well know species, i.e., small trees with no Tongan names, were probably misidentified). Observations of the vegetation were also made during a circumnavigation by ship around the island, particularly on the sides not visited during the terrestrial reconnaissance.

5. Botanical survey of Kao and Tofua

5.1 Previous Floristic Work

Floristically, Tonga is part of the "Fijian Region" that extends from the Santa Cruz Islands and Vanuatu to Niue (Takhtajan, 1969). Lying in the eastern portion of this region, Tonga has a smaller native flora than the Melanesian islands to the west, which lie closer to the Indo-Malayan source region. The first botanical collections in Tonga date to the three visits by the Cook expeditions (1773, 1774, 1777), and are stored at Kew. The next large collection was not made until over 60 years later, when the U.S. Exploring Expedition visited Tonga in 1840 (Pickering, 1876). This collection is stored mostly at the Smithsonian.

It was another half century before further major collections were made--by J.J. Lister (Hemsley, 1894) who botanized in Tonga in 1888--1891, and C.S. Crosby who botanized there in about 1894 (Burkill, 1901). These two collections are stored at Kew. Another large collection made by H.E. Parks in 1921, which is stored at Kew, the University of California Berkeley, and Bishop Museum, has only been partially published(Yuncker,1957).

However, the five largest Tongan collections (which include between 1000 and 3300 specimens), have been made in the last half-century. The first of these was by T.G. Yuncker in 1953, who, on the basis of his specimens and those of an earlier collector (H. Hurlimann in 1951), published a flora, *Plants of Tonga* in 1959. His collections are stored at the Bishop Museum. Several years later, a major collection was made by M. Hotta in 1961, but the

manuscript with the compilation of his work (Hotta, 1962) has never been published. His specimens are stored in Kyoto, Japan.

More recently, G. Buelow, who worked in Tonga between ca. 1977 and 1982, complied the largest collection of anybody (ca. 3300 numbers), but his work has never been published. His specimens are stored at Christchurch and the Bishop Museum. At about the same time another significant, but smaller, collection was made by W. R. Sykes, which is a basis for his fern study of 'Eua (Sykes, 1977) and a vegetation study of Late (Sykes, 1981). However, Sykes collection numbers to his specimens, which are stored at Christchurch, have never been published.

The most recent large collection of Tongan plants was made by the co-author (A. Whistler) during his work in Tonga (1984--1997). Information from these collections and field work are the basis of several publications (Whistler, 1989; 1991a; 1991b; 1992 a; 1992b), but little taxonomic work has been done on the specimens collected. His collections are stored at the University of Hawaii and elsewhere. In addition to these large collections, the relatively small collections of H. Hurlimann and P. Kirch were used as a basis for a checklist of the flora of Niuatoputapu published by H. St. John (St John, 1977).

Only a few of the botanists who have collected in Tonga have actually botanized on Kao and Tofua. The first collections from there date to 1953 when T.G. Yuncker (or, probably, his Tongan botanical assistant) visited Kao in 1953 and collected about 105 numbers. The next collector was M. Hotta, who visited both Kao and Tofua in 1961 and collected about 125 numbers. In 1967, Mrs. V. Scarth-Johnson collected about 162 numbers from Tofua, but these collections have never been studied. G. Buelow visited Kao and Tofua and 1977 and 1982, and his collections are the largest of any of the others (ca. 990 numbers). During the current study, 196 specimens were collected by the co-author (A. Whistler). The collections of all these botanists have gone into the annotated checklist of the flora of Kao and Tofua shown in Table 2 in Appendix 2.

5.2 Previous Vegetation Studies

There have been several recent vegetation studies in Tonga, the earliest of which was a brief paper on the forests of 'Eua (Straatsmans, 1964). A more recent and comprehensive study of the vegetation of 'Eua was done by Drake et al.(Drake *et al*, 1996). Vava'u has recently been studied by Drake, but his results have not yet been published. There have been two vegetation studies on Tongatapu, the first by Palmer (Plamer,1980) on the only remaining patch of (disturbed) lowland forest on the island, and the second by Ellison (1990) on the vegetation of the Tongatapu outliers.

The only published study on the vegetation of the volcanic islands of Tonga was by G. Uhe (Uhe,1974) for the volcanic areas of Niuafo'ou. Sykes (1981) reported on the vegetation and flora of Late, but did not include any quantitative data. A comprehensive field study of the vegetation and flora of Kao and Tofua was carried out in 1982 by G. Buelow, but the work was discontinued and never prepared for publication.

5.3 Floristic Methodology

Checklists of plant species found by the survey team during hiking to and working in the various study sites were compiled. Voucher specimens were also collected and were pressed in the evenings. These were dried by placing the presses over low heat from a campfire during the days and some of the nights. An annotated checklist of the flora of Kao and Tofua is found in Table 2. Voucher specimens collected during the survey are listed in this table. These vouchers are stored in the collections of A. Whistler at the University of Hawaii herbarium, with duplicates to be sent to Auckland Museum and other institutions.

Prior to the survey, a checklist of the flora to Tonga was compiled. This included information from literature on the flora (Hemsley 1894; Burkill, 1901, Yuncker, 1957; Hotta, 1962; St John,1977; Sykes, 1977; Sykes, 1981) and from a study made by the co-author (Whistler) of Tongan collections stored at the Bishop Museum, Kyoto University, Christchurch, the University of California Berkeley, and Kew.

After the field survey, the collections at the Bishop Museum were again searched, which turned up much of the large collection of G. Buelow made in Kao and Tofua in 1982, which has not been published. This combination of field survey, literature review, and herbarium study is the basis for the attached annotated checklist (Table 2, Appendix 2). It is fairly complete, but a few additional species would possibly turn up if the first set of Buelow's collections stored at Christchurch were to be studied.

5.4 Results

The results of the study are divided here into two parts, flora and vegetation, and are followed by the conclusions.

5.4.1 Flora

A checklist of the flora of Kao and Tofua, which includes 205 native species, is found in Table 2. A summary of the flora with the totals for each of the five groups--angiosperms (flowering plants, i.e., dicots and monocots), gymnosperms, ferns, and fern allies broken down separately is found in Table 1, Appendix 2. Of the 205 native species reported from the two islands, Tofua has 87% and Kao 79%.

Tonga is estimated to have a native flora of 451 species, thus the flora of Kao and Tofua includes nearly half (46%) of the native plants known in the archipelago. However, the number of native species on Kao and Tofua is small compared the number on the larger islands. Hotta (1957) determined that 'Eua has 191 species, Tongatapu has 172, and Vava'u 154 (although these figures are in need of some revision because of the large collections made since 1962).

There are only about a dozen endemic species in the archipelago (Whistler 1989), totaling about 3% of the flora (Whistler, 1992b). Of these endemics, only four are found on Kao and Tofua (*Syzygium crosbyi*, *Guioa lenticifolia*, *Pneumatopteris macroptera*, and *Selaginella yunckeri*). Of the four endemic species, only one, *Selaginella yunckeri*, is endemic to Kao and Tofua. It is

likely, that upon further taxonomic study, this Kao/Tofua endemic will be combined with some other nearby species and will be eliminated as a Tongan endemic. Another species, *Scaevola gracilis*, was previously considered to be endemic to Kao and Tofua, but the Tongan population appears to be identical with that on the Kermadec Islands to the south. A third species named as endemic to Kao and Tofua, *Psychotria kaoensis*, has no significant differences from the widespread *Psychotria insularum* recognized in the present study.

In addition to the native species, a total of 78 exotic (introduced) species were recorded (see Table 2) on Kao and Tofua. Of these, 28 are considered to be Polynesian introductions and 50 are modern introductions. Hotta (1957), who may not have used the same criteria as the present co-author (i.e., introduced before ca. 1800) and who worked well before the largest collection was gathered (that of Buelow) noted only 15 naturalized species on Tofua and 10 on Kao.

Also found on the island are a number of introduced cultivated plants that are not naturalized, i.e., their continued presence on the island depends upon human agency. A listing of the 47 recorded species can be found in Table 3. This list is based upon observations by the survey team and by discussions with inhabitants of the Ha'apai islands who have visited Kao and Tofua.

5.4.2 Vegetation

Like the rest of Polynesia, Tonga, which has been inhabited for over 3000 years, has been extensively modified by human activity. This disturbance has led to the loss of much of the native vegetation that once covered the islands. The loss was greatest on the lowest, smallest, most fertile islands. However, the more sparsely inhabited (and volcanically active) islands like Kao and Tofua have some of the best remaining flora and vegetation in all of Tonga.

Vegetation is often categorized and discussed by botanists in units called "plant communities," on the basis of structure, flora, and other factors. The distinctions between these "communities" are not always clear, because nature does not like to be categorized and intermediate types are common. However, for the purposes of description, the vegetation of Kao and Tofua is divided up into five categories--Disturbed Vegetation, Fernland Vegetation, Littoral Vegetation, Volcanic Vegetation, and Rainforest Vegetation--containing 10 plant communities as discussed below.

I. Disturbed Vegetation

This category of vegetation comprises managed land, secondary scrub, and secondary forest. Fernland is often included in this category, but will be discussed next under "Fernland Vegetation." Since disturbed communities are not usually natural (i.e., most are anthropogenic), or at least are not climax vegetation types, they, except for Secondary Forest, are discussed only briefly here.

1. Managed Land

Managed land comprises roads, villages, airports, and plantations that are actively prevented from returning to natural vegetation. On Kao and Tofua, however, which lack roads and airports, managed land includes mostly coconut plantations (some of them now abandoned), village sites (on Tofua), agricultural plots, and trails.

Managed land is dominated by cultivated and invasive alien (non-native) species. The actively maintained plantations are dominated by coconuts and kava, along with some subsistence crops such as yams, sweet potato, and taro. In addition to these cultivated species, many invasive alien species (included in Table 2, Appendix 2) are common in these areas, especially in places no longer managed (as when a kava patch is abandoned). The most common of these aliens include *Triumfetta rhomboidea* (mo'osipo), *Indigofera suffruticosa* ('akauveli, indigo), *Ricinus communis* (lepo, castor bean), *Passiflora foetida* (vaini ai kuma, love in a mist) *Digitaria setigera*, and *Dioscorea bulbifera* (hoi, bitter yam). Native plants, such *as Morinda citrifolia* (nonu) and *Miscanthus floridulus* (kaho), and ferns such *as Nephrolepis hirsutula* (hulufe) and *Sphaerostephanos* spp. may also invade these abandoned agricultural areas like other invasive species. Areas that have been extensively damaged, especially by continual burning, often turn into toafa (fernlands), which are very similar to some stages of managed land (but which lack a dominance of ferns) and are discussed below under fernlands. Nearly all of the managed land on the two islands is on Tofua, since Kao has largely been abandoned and no current plantations or villages were noted during the visit.

2. Secondary Scrub

This is the scrubby vegetation that occurs on recently abandoned land. The first invaders are herbaceous invasive species, but if the land is left undisturbed for long enough, characteristic shrubs and small tree species soon take over. The plants that dominate here typically are fast growing and have effective modes of long-distance seed dispersal. Most of them are light-loving species that disappear in later successional stages--when secondary scrub is replaced by secondary forest and the forest floor becomes shaded.

On Kao and Tofua, the most characteristic shrubs and young trees of secondary scrub are *Glochidion ramiflorum* (malolo), *Morinda citrifolia* (nonu), *Macaranga harveyana* (loupata), *Mussaenda raiateensis* (monomono a hina), *Dodonaea viscosa*, *Rhus taitensis* (tavahi), *and Alphitonia zizyphoides* (toi). Excessive burning at this stage probably leads to toafa (fernlands).

3. Secondary Forest

Secondary forest is the high forest dominated[7] by shade-intolerant trees that typically become established in sunny conditions in disturbed areas. Secondary forest trees grow

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[7] Dominance, as used here, is determined by biomass, which is estimated by measuring the basal diameter at breast height (dbh) of all the trees in a plot. Dhb is a basic measurement used by foresters and botanists to measure tree diameters. Relative dominance, as used here, is determined by adding the basal diameter

taller than those of secondary scrub and produce a shade that eventually eliminates the smaller species. The seeds of dominant secondary forest trees do not germinate or grow well in shade, so as the mature trees grow and die, the secondary forest species are eventually replaced by other tree species (primary forest trees) that are adapted to germination and early growth in the shady conditions of mature forest.

Secondary forest on Tofua is concentrated on the outer crater slopes of the north and east sides where most of the agriculture has been carried out in the past (**Fig. 11**), and on the margins of fernlands of Kao. At the older stages of secondary forest, its structure may appear very similar to lowland forest, making it hard to map this vegetation without site visits, especially since it probably occurs in a mosaic with lowland forest.

The secondary forests of Tonga in general and Kao and Tofua specifically are mostly dominated by *Rhus taitensis* (tavahi), *Alphitonia zizyphoides* (toi), *Neonaudea forsteri* (afa), and *Elattostachys falcata*(gatata)(Straatmans, 1964, Whistler, 1992b). In addition to these, *Casuarina equisetifolia* (toa), which dominates littoral forest and the tree layer of fernlands and volcanic areas, is a common component of secondary forest on Kao and Tofua, as well on as other Tongan volcanic islands, such as Late.(Sykes, 1981).

Although these secondary forest trees dominate at the present time, the composition of dbh sizes (as measured during the present survey) indicates that secondary forest trees are uncommon or absent in the smaller size classes, where small individuals of primary canopy trees are common. The dominant canopy tree individuals of the smaller size classes will eventually replace the trees currently dominating the canopy. This indicates that after a certain period of time (several decades), the secondary forest species will eventually disappear (or nearly disappear) in the canopy and will be replaced by primary forest species--until the next disturbance.

Two quite different plots of secondary forest were sampled during the survey on Tofua, nos. 1 and 2. Plot no. 1 was in a coastal area at about 40 m elevation, and was in what may have once been (before disturbance) a "coastal forest" noted under lowland forest, because of the presence of *Diospyros elliptica* (kanume), *Planchonella grayana* (kalaka), *Guettarda speciosa* (puopua), *Pandanus tectorius* (fafa), *Grewia crenata* (fo'ui), and *Diospyros samoensis* (tutuna). These species are typically absent from the lowland forest on the rim and inner slopes of Tofua, but common near the coast. The two dominant species of Plot 1, *Casuarina equisetifolia* (toa) and *Ficus obliqua* (ovava) were both represented by only two large individuals each. The third dominant, *Rhus taitensis* (tavahi), was represented by 34 individuals (more than three times as many as any other species), most of them less than 15 cm dbh. This indicates that tavahi is taking over the forest, i.e., it is becoming the dominant species since the first two species are not replacing themselves. Other indicator trees of secondary forest present in the plot included *Elattostachys falcata* (ngatata) and *Alphitonia zizyphoides* (toi).

Plot no. 2 was dominated by *Neonaudea forsteri* (afa), but 7 of the 9 trees present were large (over 15 cm dbh). Other secondary forest indicator trees, ranking 3rd to 5th in relative dominance, were *Cyathea lunulata* (ponga), *Elattostachys falcata* (ngatata), and *Rhus taitensis*

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figure for all individuals of a species and dividing this by the sum of the basal areas of all of the trees of all species in the plot.

(tavahi). The second dominant was *Calophyllum neo-ebudicum* (tamanu), which is probably well on its way to becoming the dominant tree in a lowland forest.

Another type of secondary forest noted during the survey was a fern forest dominated by *Cyathea lunulata* (ponga) and occurring in a relatively narrow patch (or band) on at least the south side of Kao island sandwiched between the lowland forest and the toafa at about 420 m elevation. Its origin and extent on the island are unknown. Other significant tree species mixed in with the tree ferns included *Alphitonia zizyphoides* (toi) and *Casuarina equisetifolia* (toa). The ground cover was dominated by the ferns *Christella harveyi*, *Sphaerostephanos* sp., *Dicranopteris linearis* (kahiva'e), and *Blechnum vulcanicum*. A natural forest of similar composition seen on the east inner slope of Tofua was dominated by *Cyathea lunulata*, with lesser amounts of *Alphitonia zizyphoides* and *Rhus taitensis* (tavahi), with the ground cover dominated by *Sphaerostephanos* sp.

II. Fernland Vegetation

This is the vegetation dominated by perennial fern species. It is a somewhat heterogeneous group composed of anthropogenic fernlands (disturbed fernlands created and maintained by the activities of man) and natural fernlands. The former is described here under "Toafa" community, with two variations recognized, and the latter is described under "Montane Fernland" community.

4. Toafa (Fernland)

This fernland vegetation, called "toafa" in Tongan, is a subclimax community dominated by herbaceous species, typically ferns that are adapted to fires (mostly intentionally set) that periodically raze the vegetation. Two associations are recognized on Kao and Tofua, one dominated by *Dicranopteris linearis* (kahiva'e) and the other by *Pteridium esculentum* (probably also called kahiva'e), a fern not reported from elsewhere in Tonga. The area covered by these ferns was probably originally lowland forest, but shifting agriculture and periodic burning keep the soil impoverished and prevents forest trees from becoming established. These fernlands are apparently maintained by capricious rather than purposeful burning, since the fernlands are not used for anything.

A. *Pteridium* Toafa

This fernland, dominated by the fern *Pteridium esculentum*, is found at the lower elevations of both Kao and Tofua (**Figs. 11 & 12**). At higher elevations, i.e., above about 350 m on Tofua, it is replaced in dominance by the other similar species, *Dicranopteris linearis*.(**Fig. 13**) It is not clear why *Pteridium* has this dominance pattern, since *Dicranopteris* is known to dominate at low elevations elsewhere in Tonga (where *Pteridium* is absent). *Pteridium* toafa was seen during the survey on the north and east sides of the outer slope of Tofua, and at the base of the south slope of Kao.

In addition to *Pteridium esculentum*, other common herbaceous species present include *Nephrolepis hirsutula* (hulufe), *Sphaerostephanos* spp., and *Miscanthus floridulus* (kaho). Less common species include *Spermacoce assurgens*, *Digitaria setigera*, *Sida rhombifolia* (te'ehoosi), *Tacca leontopetaloides* (mahoa'a, Polynesian arrowroot), *Paspalum scrobiculatum*, *Vernonia cinerea*,

Figure 11. Typical disturbed vegetation on the upper eastern slopes of Tofua. Toafa fernland of kahiva'e in the foreground, and secondary forest of tavahi, toi and afa. The forest has been recently burnt.

Figure 12. A different kind of toafa fernland, with kahiva'e under an open woodland cover of toa and ponga.

Desmodium heterocarpon, *Ipomoea littoralis*, *Conyza bonariensis*, *Spathoglottis plicata*, and *Bidens pilosa* (fisi'uli, beggar's tick). Other species, such as *Triumfetta rhomboidea* (mo'osipo) and *Chrysopogon aciculatus* (mata pekepeka), are frequent along trails.

Scattered trees are also present, but these are mostly small individuals of *Casuarina equisetifolia* (toa). Secondary forest tree species are also present, especially *Alphitonia zizyphoides* (toi) and *Rhus taitensis* (tavahi), but these are present mostly as saplings. Shrubs are much more numerous, especially *Dodonaea viscosa*, *Wikstroemia foetida*, *Morinda citrifolia* (nonu), *Premna serratifolia* (volovalo), *Geniostoma rupestre* (te'epilo a maui), *Mussaenda raiateensis* (monomono a hina), *Glochidion ramiflorum*, and *Melastoma denticulatum*.

B. *Dicranopteris* Toafa

This fernland is dominated by *Dicranopteris linearis*, and is a common community in Tonga, especially on 'Eua. Like the *Pteridium* toafa, it is probably maintained by burning, which kills most tree species that are not adapted to fire. This fernland occurs on Tofua above about 350 m elevation on the north and probably the east side of the island (**Fig. 13**), while on Kao it was first recorded at 450 m elevation on the south-facing slope. At its upper elevations, the dominant species is replaced by *Blechnum vulcanicum* (**Fig. 14**)in a community called Montane Fernland (discussed next).

Although *Dicranopteris linearis* usually dominates in this fernland, other species are sometimes equally or more important, especially just after an area has been burned. This includes the herbaceous species *Lycopodium cernuum*, *Selaginella yunckeri*, *Imperata cylindrica*, *Nephrolepis hirsutula* (hulufe), *Sphaerostephanos* spp., *Dianella ensifolia* (afuafu), *Spathoglottis plicata*, *Paspalum scrobiculatum*, *Fimbristylis dichotoma*, *Lindsaea ensifolia*, *Spermacoce assurgens*, *Conyza bonariensis*, *Aster subulatus*, *Blechnum vulcanicum*, and *Pteridium esculentum*; the shrubby species *Dodonaea viscosa*, *Glochidion ramiflorum* (malolo), *Scaevola gracilis*, *Melastoma denticulatum*, *Maoutia australis*, *Wikstroemia foetida*, *Cyathea* spp. (ponga), and *Geniostoma rupestre* (te'epilo a maui); and scattered small trees of *Casuarina equisetifolia*. At a later stage of succession, perhaps when the fernland hasn't been burned in a while, the toa trees may take over to form an open forest with a dense understory of *Dicranopteris*, described under the volcanic vegetation category below.

In the fernlands on Kao at about 530 m elevation and above, vegetation dominated by *Dicranopteris* are interspersed with areas dominated by *Paspalum scrobiculatum*, *Fimbristylis dichotoma*, *Imperata cylindrica*, *Melastoma denticulatum*, and *Maoutia australis*, but why these two types exist in a mosaic is not clear, although fire history is a probable cause.

5. Montane Fernland

This type of vegetation, which is apparently found only on the upper slopes of Kao (**Fig. 14**), differs from any other in Tonga and was not included in the vegetation outline of Tonga (Whistler, 1992b). Its most characteristic feature is the dominance of the fern *Blechnum vulcanicum*. It is composed almost entirely of herbaceous plants, and, in fact, no trees were seen above about 450 m elevation. The reason for the absence of montane forest at this elevation is unclear, since at similar elevations in the area (Samoa) montane rainforest or

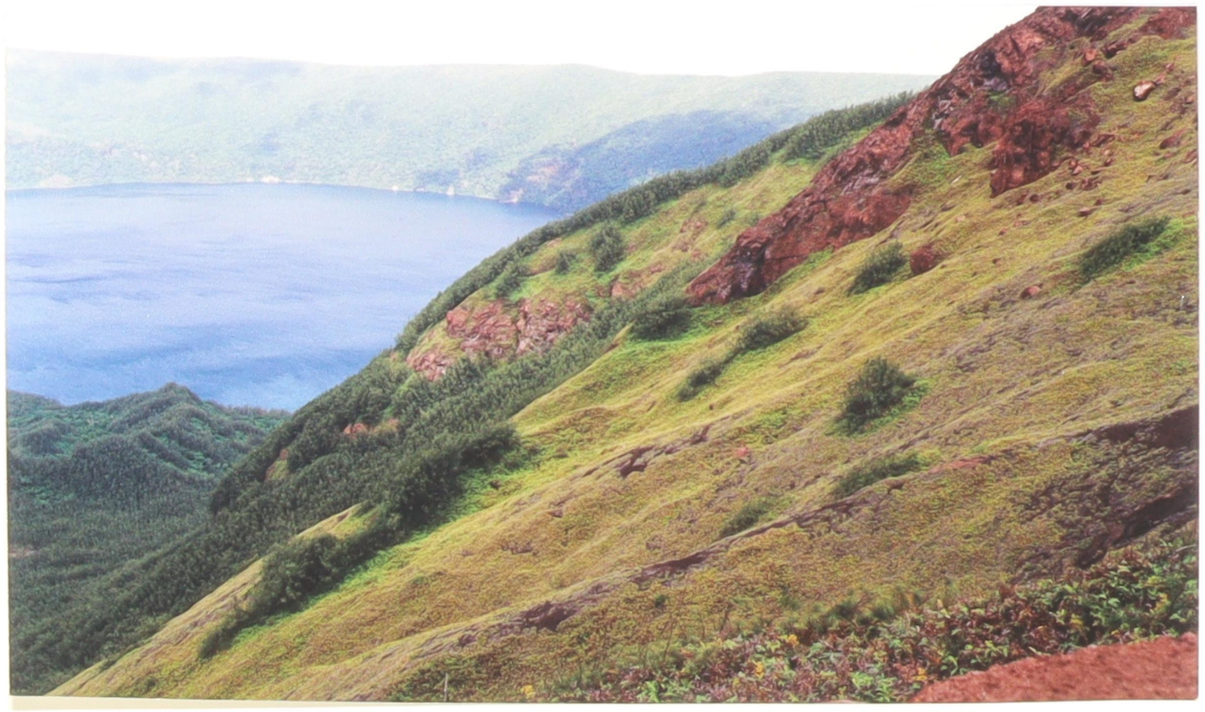

Figure 13. Toafa fernland of *Dicranopteris linearis* on Tofua. The crater lake is in the background.

Figure 14. Montane fernland dominated by *Blechnum vulcanicum* on the upper slopes of Kao at 330m

cloud forest dominate. However, although this fern species also occurs on Tofua, it does not form a distinct community as it does on the higher island of Kao.

On Kao, *Blechnum vulcanicum* was recorded from 450 m up to the summit at 1040 m elevation. At the lower elevations, between 450 and 900 m, it often shares dominance with *Dicranopteris linearis* (kahiva'e), and to a lesser extent, *Lycopodium cernuum*. Also common in this intermediate zone are shrubs of *Geniostoma rupestre* (te'epilo a maui), *Melastoma denticulata*, and *Cyrtandra samoensis*, the monocots *Fimbristylis dichotoma* (a sedge), *Imperata cylindrica* (a grass), and *Spathoglottis plicata* (an orchid), and unidentified mosses. Also present in the upper elevations is *Cyathea decurrens*, a new species record for Tonga first collected by Buelow.

This fernland is usually less than 1 m in height, but may be taller in small gullies. In some of the deeper gullies, tree ferns, probably *Cyathea lunulata* (ponga) form small stands. In some areas there are barren rock, possibly caused by heavy run-off after rains.

III. Littoral Vegetation

This category is sometimes divided into four components-- herbaceous strand, littoral shrubland, pandanus scrub, and littoral forest. However, several factors tend to blur the distinctiveness of these units: (1) they are usually narrow zones of vegetation; (2) one or more are frequently missing from coasts; and (3) boundaries between them are sometimes indistinct. Because of these reasons, and because the first three components are such narrow zones on Kao and Tofua, the littoral vegetation is discussed here as two communities, "littoral strand" and "littoral forest."

6. Littoral Strand

This is a zone of herbaceous and/or shrubby littoral vegetation that is often found between the littoral forest and the sea. Most of the coasts of Kao and Tofua are composed of cliffs and steep slopes of basalt, and these are typically dominated by a sparse to dense cover of littoral herbs and shrubs. The most common shrubs are *Pemphis acidula* (ngingie), *Scaevola taccada* (ngahu), and *Wollastonia biflora* (ate). In some places there are dense patches of *Pandanus tectorius* (fafa), which is sometimes put into its own community, pandanus scrub. The most common herbs are *Lepturus repens*, *Stenotaphrum micranthum*, *Ipomoea pes-caprae* (fue kula), and *Canavalia sericea* (fue veli).

7. Littoral Forest

This is the forest occurring in a narrow zone on rocky or sandy shores, between the lowland or coastal forest on its inland side and the ocean on its seaward side. It is dominated by a small number of tree species, some of them becoming quite massive, that are typically dispersed by buoyant, saltwater-resistant seeds or fruits. These trees are nearly always widespread species that are resistant to the brackish ground water and salty sea winds--major factors that exclude inland trees from coastal areas. Most littoral trees rarely occur very far inland (*Casuarina equisetifolia* being an exception), possibly because of their limited

dispersal mechanisms and because of competition from lowland and coastal forest trees. The forest floor often has only a sparse ground cover, since littoral shrubs and herbs are usually heliophytes that cannot survive in the shade of the forest.

On Kao and Tofua, the littoral forest is typically dominated by *Casuarina equisetifolia* (toa), (**Fig. 15**) which is probably an ancient introduction rather than a native species. The forest also includes an understory of smaller trees, particularly *Neisosperma oppositifolium* (fao), and lesser amounts of *Pandanus tectorius* (fafa, screwpine), *Guettarda speciosa* (puopua), *Hernandia nymphaeifolia* (fotulona, Chinese lantern-tree), *Hibiscus tiliaceus* (fau, beach hibiscus), and coconuts (especially near former villages). *Some Tournefourtia argentea* (touhuni, tree heliotrope) and *Thespesia populnea* (milo, Pacific rosewood) are also present on the seaward margin.

Most of the littoral forest on Tonga is on a limestone substrate, and is typically dominated by *Barringtonia asiatica* (futu, fish-poison tree), *Calophyllum inophyllum* (feta'u, Alexandrian laurel), *Hernandia nymphaeifolia* (fotulona), *Terminalia catappa* (telie, tropical almond), *Excoecaria agallocha* (feta'anu), or *Pisonia grandis* (puko). These species are absent or rare in the littoral forests of Kao and Tofua. Only one small patch of *Pisonia grandis* was seen on the coast (during a circumnavigation of Tofua). Littoral forest dominated by *Casuarina* and *Neisosperma* was also noted on Late (Sykes, 1981).

IV. Volcanic Vegetation

The fourth category, volcanic vegetation, comprises two types of vegetation--volcanic scrub and toa (*Casuarina*) woodland. However, the two are not always distinct from each other

8. Volcanic Scrub

This is the scrubby vegetation that occurs on the recent volcanic substrates of Tofua--lava and ash deposits--that are mostly on the rim and inside the crater. Kao does not really have this type of vegetation since it has not been recently volcanically active and lacks the fresh volcanic substrates. This category is somewhat intermediate between fernlands and toa woodland (discussed next). The interaction between anthropogenic disturbance (mainly fire) and volcanic activity has created a mosaic of vegetation types that are distinguished from each other only with difficulty.

Volcanic scrub occurs on several of the small, volcanically active islands in Tonga--Niuafo'ou, Late, Fonualei, Kao, and Tofua. On Niuafo'ou, Uhe (1974a) recorded the most common species on a 1929 flow as *Morinda citrifolia*, *Glochidion ramiflorum*, *Pipturus argenteus*, and *Macaranga harveyana*, and the most common herbaceous species as *Nephrolepis hirsutula*, *Phymatosorus scolopendria*, *Davallia solida*, *Psilotum nudum*, and *Hoya australis*. On the high volcanic island of Late, *Casuarina equisetifolia* dominates from the shore up to near the summit of the island (Sykes, 1981).

On Tofua, this vegetation is quite open, with scattered patches of vegetation, and some volcanic substrates are still quite barren (**Fig. 16**). The dominant species on the lava flows encountered inside the crater during the survey are *Dicranopteris linearis* (kahiva'e), with lesser amounts of *Davallia solida* (kulutuma), *Dendrobium calcaratum*, and *Fagraea berteroana* (pua).

Figure 15. The steep western slopes of Kao showing the gradation from littoral forest dominated by toa up to montane fernlands above the limit of forest growth.

Figure 16. Typical volcanic vegetation dominated by patches of toafa, on the western crater rim of Tofua.

Figure 17. Toa trees colonising ash deposits on the upper eastern slopes above the Tofua crater. This is the initial stage

Figure 18. The pattern of toa woodland colonisation of lava within the Tofua crater. Note the birdsfoot pattern by which the lava flows have entered the crater lake.

Also present but less common are *Lycopodium cernuum*, *Melastoma denticulatum*, *Geniostoma rupestre* (te'epilo a maui), *Dodonaea viscosa*, and *Imperata cylindrica*, as well as mosses and lichens characteristic of lava flows.

Ash deposits occur on the north and northwest rim of the caldera, and inside the crater in volcanic areas. The vegetation on these is sometimes intermediate between toa woodland and fernlands, and are often difficult to categorize, especially when they have recently burned. This substrate is dominated by scattered trees of *Casuarina equisetifolia* (**Fig. 17**), the *shrubs Dodonaea viscosa*, *Cyrtandra samoensis*, *Geniostoma rupestre* (te'epilo a maui), and *Scaevola gracilis*, and the herbaceous plants *Dicranopteris linearis* (kahiva'e), Lycopodium cernuum, *Sphaerostephanos* sp., *Spathoglottis plicata*, and many others.

9. Toa (*Casuarina*) Woodland

This vegetation is characterized by the dominance of *Casuarina equisetifolia* (toa) trees (**Fig. 18**). Other types of vegetation on Kao and Tofua (noted above) also have significant amounts of toa, and the separation of these is somewhat tenuous(**Figs. 19 & 20**). Toa dominates littoral forest, in volcanic areas within the crater, and is the main tree on the fernlands. What usually distinguishes these three is that the first is in volcanic areas and is dominated by toa, the second is littoral and contains a significant littoral flora component, and the third is dominated by ferns and not trees.

Toa woodland is not usually a closed forest, since the trees are typically spaced and do not produce a dense canopy. Consequently, ferns, particularly *Dicranopteris linearis* (kahiva'e), often dominate the ground cover. Also common are the ferns *Nephrolepis hirsutula* (hulufe), *Histiopteris incisa*, *Lycopodium cernuum*, *Cyathea lunulata* (ponga), and *Lindsaea ensifolia*, and shrubs such as *Geniostoma rupestre*, (te'epilo a maui), *Pipturus argenteus* (olonga), *Glochidion ramiflorum* (malolo), and *Melastoma denticulatum*.

V. Rainforest Vegetation

The fifth category of vegetation comprises rainforest (**Figs. 21 & 22**), the vegetation that originally covered nearly the entire surface of Tonga (a notable exception being areas of recent volcanic activity). It is typically a tall forest with a canopy up to 30 m or more in height in some places, and has a great diversity of species, including epiphytes, terrestrial herbs, and lianas. The woody plants can be divided into canopy trees, subcanopy trees, understory trees, and shrubs, but distinct layers are not usually recognizable.

Rainforest is often divided into several communities based upon differences in dominant species. These differences are related to proximity to the coast and to elevation, which in turn affect temperature and rainfall. These characteristics, along with edaphic factors, are the major determinants of species distributions. However, since Kao and Tofua are covered with relatively homogeneous, recent volcanic surfaces, and the forests seen do not extend above 500m in elevation, the lowland forests present are all considered to ne the lowland forests previously described (Whistler, 1992b).

Figure 19. Closed toa woodland and gully forests of ponga above the northwestern shore of the Tofua crater lake.

Figure 20. Older closed toa woodland being succeeded by primary rainforest of tamanu and makai on an old lava flow above the western shore of the crater lake.

Figure 21. Tamanu and makai dominated primary rainforest in the main Tofua crater.

Figure 22. Interior of the forest in Figure 21,

A variant of rainforest, coastal forest, is sometimes recognized in Tonga (Whistler 1992b). It is characteristically dominated by *Syzygium dusiifolium*, *Syzygium dealatum*, *Diospyros elliptica*, and *Diospyros samoensis*. These and other coastal forest trees usually have colorful, bird-dispersed fruits, unlike trees typical of littoral forest. Coastal forest sometimes intergrades with littoral forest, and in some places large littoral forest trees, such as *Pisonia grandis*, may be mixed with the *Syzygium* and *Diospyros* trees. Although all the above noted species are present on Kao and Tofua, no distinct coastal forest was noted during the brief survey of the islands, but may be present in areas not visited. Only lowland forest is recognized here.

10. Lowland Forest

The lowland forest of Kao and Tofua is not homogeneous (**Fig. 25**), since two different tree species were dominant in the four lowland forest plots sampled during the survey (see Table 5). By using only the data in these plots, one might conclude that two associations exist on the islands--tamanu (*Calophyllum*) forest and makai (*Canarium*) forest. However, if many more plots were sampled, it is likely that these differences would be blurred because the tree species are distributed somewhat independently of each other. Disturbance to the forest, both manmade and natural, also causes the distinctions to blur because it causes the forests to be in a state of succession with one or more species replacing another. Nevertheless, the two types of forest, tamanu forest and makai forest, will be discussed separately here.

A. Tamanu Forest

This association, dominated by *Calophyllum neo-ebudicum* (tamanu), is the most common type of forest on Kao and Tofua (**Figs. 23 & 24**). On 'Eua, Drake et al, 1996) recognized a very similar association as "*Calophyllum* mixed forest" and Straatmans (1964) referred to it as "*Calophyllum-Elattostachys* association." Tamanu forest is represented by plot nos. 3 (on Kao) and 4 (on Tofua).

Tamanu dominated these two plots, with an average of 45% relative dominance In the Kao plot the number of individual tamanu trees was 82 while in the other it was 14, but it is not clear why the former figure was so high. Other important species present were *Elattostachys falcata* (ngatata) with 11% relative dominance, *Syzygium brackenridgei* (fekika vao) with 10%, *Alphitonia zizyphoides* (toi) with 8%, and *Canarium vitiense* (makai) with 4%. The canopy is over 15 m high in all the lowland forests seen.

The ground cover can be quite variable in tamanu forest. In the Kao plot, the forest floor was quite open, with the relatively sparse ground cover dominated by the fern *Christella harveyi*. In the Tofua plot, which may have been in a wetter locale (at 400 m vs. 250 m elevation) the ground cover was dense and was dominated by the ferns *Christella harveyi*, *Arachniodes aristata*, *Marattia smithii*, and *Pteris comans*. Other common terrestrial ferns included *Angiopteris evecta*, *Nephrolepis hirsutula*, and *Loxoscaphe gibberosum*. Flowering plants are relatively sparse, with the exception of *Alyxia stellata* (maile), *Macropiper puberulum* (kavakava 'ulie), tree seedlings, and terrestrial orchids (especially *Erythrodes oxyglossa*, *Erythrodes parvula*, and *Calanthe hololeuca*).

Lianas are also frequent in lowland forest. The most common species are *Faradaya amicorum* (kili?), *Jasminum simplicifolium* (tutu'uli), *Rourea minor*, *Morinda myrtifolia*, and *Gynochtodes epiphytica*.

Figures 23 and 24. Interior of tamanu forest on eastern crater rim of Tofua.

Figure 25. Steep slope lowland rainforest on the south-eastern slopes above the crater lake. This indicates the very difficult terrain of much of the forested part of Tofua.

Figure 26. Makai dominated primary rainforest on the same lava flow as illustrated in Figure 20.

Epiphytes are sparse to moderate (depending upon how wet the forest is), with the most common species being the filmy ferns *Trichomanes saxifragoides*, *Trichomanes humile*, and *Hymenophyllum polyanthos*, other ferns, such as *Loxoscaphe gibberosum*, *Humata heterophylla*, and *Davallia solida*, and orchids, such as *Dendrobium calcaratum*, *Phreatia micrantha*, and *Bulbophyllum* cf. *membranaceum*.

B. Makai Forest

Two other plots were dominated by *Canarium vitiense* (makai), which is not recorded from the literature since in Tonga this species is restricted to Kao and Tofua. Makai showed up in all four lowland forest plots, but was a relatively minor component in the two dominated by tamanu. The relationship between these two types of forest is not clear, but could be successional with makai forest replacing tamanu forest over time. On the other hand, it could also be that the two are somewhat separate and dominate in different soil and rainfall regimes. One of the plots, no. 6, was what appeared to be as close to primary lowland rain forest (without any signs of human disturbance) as has ever been seen in Polynesia by the co-author (A. Whistler).

In the two plots (nos. 5 and 6) of makai forest, makai had a relative dominance of 42%. Also common were tamanu with 14%, *Myristica hypargyraea* (kotone) with 13%, *Neonaudea forsteri* (afa) with 7%, *Cyathea lunulata* (ponga) with 6%, and *Alphitonia zizyphoides* (toi) with 6%. Also frequent but less dominant were *Elattostachys falcata* (ngatata), *Heritiera ornithocephala* (ifiifi), *Garcinia myrtifolia* (feto'umaka), and *Elaeocarpus tonganus* (ma'ama'alava). Two other species, *Psychotria insularum* (olavai) and *Ficus scabra* (masi ata) were frequent but small in size.

Perhaps the most characteristic difference between the two types of lowland forest is the density of trees. The number of trees above 5 cm dbh in the tamanu forest averaged 165 while in the makai forest it averaged 76--less than half as much. Also, the average size of tree of the dominant species was different: tamanu trees in the tamanu forest plots averaged 20 cm dbh while the makai trees in the makai forest plots averaged 44 cm. This supports the idea that makai forest is more of a primary forest than tamanu forest.

When the forest canopy is closed, the forest floor tends to be open and relatively free of ground cover. The flora of the forest floor is not distinguishable from that found in mature tamanu forest, and is mostly characterized by shade-loving fern species. This was particularly the case with the makai forest in Plot 6, which had a very shady forest floor. The most common of these fern species are *Angiopteris evecta*, *Pteris comans*, *Arachniodes aristata*, *Christella harveyi*, and *Trichomanes boryanum*. Also present were the flowering plants *Alyxia stellata* (maile) and *Macropiper puberulum* (kavakava 'ulie), and orchids, such as *Calanthe hololeuca*, *Erythrodes oxyglossa*, and *Erythrodes parvula*.

Lianas are frequent in makai forest, with the most common species being *Faradaya amicorum* (kili?), *Rourea minor*, *Jasminum simplicifolium* (tutu'uli), and *Gynochtodes epiphytica*. There is no apparent difference between this liana flora and that found in tamanu forest. The epiphyte flora is probably similar to that of tamanu forest, but the numbers appear to be less, at least on tree trunks. This may be due to less light in the shady makai forests.

5.5 Conclusions of the botanical survey

The botanical survey of Kao and Tofua established that these two islands contain many native plants that are no longer found anywhere else in Tonga. They also contain some of the best remaining native vegetation in Tonga.

The flora of Kao and Tofua comprises a large number of native plants, some of which are found nowhere else in Tonga. The two islands are home to 61% of the ferns, 88% (7 of 8) of the fern allies, and 65% (28 of 43) of the orchids of Tonga. Perhaps only two of the species are endemic to Tonga--one of them (*Selaginella yunckeri*) only to Kao and Tofua.

Much of the southern half of Tofua, and perhaps all around the lower elevations of Kao, is lowland forest or mature secondary forest. The upper half of Kao is covered with a native fernland vegetation dominated by a fern (*Blechnum vulcanicum*) found nowhere else in Tonga except Late. The islands' forests are some of the best ever seen by the project botanist (A. Whistler), particularly the mature makai forest inside Tofua crater (**Fig. 26**) and the tamanu forests that extend around the south half of the island. This undisturbed vegetation is of great importance to the native wildlife of the islands and its is central to the significance of Tofua and Kao in terms of the biodiversity of the Kingdom of Tonga.

Paralleling the botanical survey's identification of the biodiversity significance of Tofua and Kao's native forests and botanical values, was its recognition of the extent and degree of feral pig damage. Substantial pig damage was seen in the forests, particularly on Kao. Since the islands are only sparsely inhabited (Tofua) or uninhabited (Kao), wild pigs have nearly free run of the forests. Control of pigs will need to be a major element of future biodiversity conservation management.

The botanical survey also revealed fire to be a major threat to the vegetation. Fires are frequently being set on both islands. Several months prior to the field survey for this project, a large fire on Tofua, lasting several days, was visible from faraway Lifuka. While this burning is capricious and without economic value, and the fires are usually confined to the *toafa* fernlands, there is considerable evidence of high-quality native forest being burnt.

The third major threat to the islands' biodiversity values revealed by the botanical survey is the demand that the cultivation of kava crops is placing on native forests.

This botanical survey has demonstated Tofua and Kao to contain biodiversity values that no longer occur elsewhere in the Kingdom of Tonga. The biodiversity significance of Tofua and Kao are set out in the following section.

6. The Significance of Tofua and Kao to the Biodiversity of Ha'apai.

The Ha'apai Conservation Area Project defines biodiversity as including: *'all terrestrial and marine ecosystems, all plant and animal species and varieties found in these ecosystems, and the knowledge, uses, beliefs and language that the people of Ha'apai have in relation to their ecosystems and species'*(HCAP Preparation Document, 1995). It recognises that biodiversity is more than a matter of

scientific, economic, recreational or ecological value. It is the "capital" on which development and maintenance of the local communities is based. An important component of a biodiversity conservation plan that has such a cultural dimension is ensuring that as far as possible, any culture can continue to get information on its environment's flora and fauna, and constituent ecosystems, particularly those that have made it possible to inhabit that environment in the first place and that have sustained it historically.

6.1 The Particular Issue of Forest, and Forest Trees, as Biodiversity Assets.

It is the existence of indigenous forest, its birds included, that, more than any biodiversity feature, make Tofua and Kao special parts of the Kingdom of Tonga, and priorities for ecological survey; for the simple reason that almost everywhere else in the Kingdom, human activities have converted the forest resource into settlements or cropland.

The 1993 SPREP *Kingdom of Tonga: Action Strategy for Managing the Environment* set out how limited both the Kingdom's indigenous forest resource and knowledge of what forest remains is. Except for 'Eua, where the forested *liku* coast has recently been protected as a national park, any indigenous forest is now confined to very steep or otherwise inaccessible areas, in coastal littoral areas and swamps, or in mangrove swamps. There is a small area of indigenous forest on the volcanic island of Late in Vava'u. Even then, much of it is secondary. In the Nuias, the island of Tafahi has cloud forest on steep slopes, similar to Kao's, and other small indigenous forests occur on Nuiatoputapu No Tongan island can compare with Tofua and Kao for the proportion of the island that is still in primary indigenous forest.

The significance of any remaining forest in Ha'apai has been recognised in the Ha'apai Conservation Area's discussions with local communities to identify what they, the resource users, consider to be Ha'apai's resource problems. One of the most serious problems of both biodiversity loss and environmental degradation was considered to be the absence of forest in the modern agricultural landscape and the rapid disappearance of traditionally useful trees that is occurring with it. The problem is seen to have three causes:

- an increasing tendency towards export cropping and other intensive or short-term monocultural forms of agriculture that require the use of a plough, inorganic fertilisers, and pesticides.
- recent and widespread devastating tropical cyclones which uproot trees or kill them with salt spray or storm surge.
- a failure to replant.

The problem of deforestation and incipient tree loss is not one confined to Ha'apai. It is Tonga-wide, and is particularly serious on Tongatapu and Vava'u, where the recent expansion of squash cultivation as an export cash crop has caused unprecedented destruction of the traditional agroforestry system that has been the foundation of Tonga life for generations.

The incipient trend, now so widespread throughout Tonga, from self-regenerating forest towards open deforested land, including *toafa*, with high prospect of being repeatedly burnt, but very little prospect of forest regeneration is also common on both Tofua and Kao.

6.2 The Small-island Bird Factor - the issue of extinction

While the main reason for attributing high significance to Tofua and Kao's rainforests is because of their relative quality, for the Kingdom of Tonga, of an ecosystems of global biodiversity significance, there are specific species values that need to be highlighted. Central to this is the importance of the forests for birds.

This ecological and botanical survey did not extend to a survey of the islands' birds. But the significance of Tofua and Kao's forests as bird habitat is a major factor in their very high biodiversity value. Small island rainforest is a Pacific example of an ecosystem of global concern. Worldwide, the largest number of documented extinctions has occurred on the Pacific's small islands. It has been estimated that there are roughly 7 times more endangered bird species *per capita* in the South Pacific than in the Caribbean, 50 times more than in South America, and 100 times more than in North America or Africa (SPREP/UNDP/GEF, 1993).

This pattern of extinction has its origins in the principle that the birds of the small-island Pacific evolved in environments free of mammalian predators and thus had little defence against both people and the animals they brought into the Pacific with them. In the case of Tofua and Kao and the rest of Ha'apai, the pattern of extinction reaches back to the very beginning of human settlement in these islands.

There is no doubt that many species of bird became extinct onTofua in the distant human past; as they did on every other island in Tonga once people arrived thousands of years ago. Tofua lacks prehistoric faunal evidence of the kind now comprehensively available for many of Ha'apai's islands. However, ornithologists familiar with the faunal extinction trends in the region believe that certainly all the extinct flying species discovered in archaeological excavations on Ha'apai's non-volcanic islands, and most likely the various megapodes and flightless rails, also used to live on Tofua (Steadman, 1998).

The evidence throughout Ha'apai is that once people first encountered its archipelago of small islands, about 3000 years ago, they radiated across its entirety so rapidly that in the host of sites where the beginning of settlement has now been dated, it is almost simultaneous everywhere (Burley, 1998, Burley *et al*,1999). The earliest birding in Ha'apai may have resembled gathering more than hunting. Archeological evidence is that birds made up a substantial portion of the diet, and there is a paucity of domesticated animals like pig or dog (Dye and Steadman 1998).

Historically, Tofua and Kao would have abounded with landbirds that thrived in virgin forest islands and seabirds that nested on or near the ground. A large volcanic island like Tofua, with fertile soils, a low human population and relatively high diversity of bird habitat compared to the atolls, limestone islands and sand cays of Ha'apai, would have supported larger bird populations, and as such would have attracted birding parties from the smaller

islands. Furthermore, its bird populations would have declined slower, and gone into extinction later.

Only a few of the land birds that once occurred in Ha'apai still survive. Most of their natural habitat has been transformed from forest to the cultural landscapes of today. This ecological transformation meant that, on most islands, the human inhabitants had to work harder to produce animal foods, and soon traded raids on birds and turtle nesting grounds for the full-time responsibilities of tending pigs, and organising efficient fishing (Dye and Steadman 1998). But land birds are still hunted throughout Ha'apai when the opportunity arises.

Lupe, the once-abundant Pacific pigeon (*Ducula pacifica*), is an excellent demonstration of the biodiversity value of Tofua and Kao to the wider Ha'apais. As the ancient raised mounds created for chiefs to hunt lupe attest, lupe was once found throughout the Ha'apais. Because of its excellent dispersal ability over oceanic water, lupe can still be seen throughout the Ha'apais, and its is still hunted when it turns up. When David Steadman undertook his recent survey of the status of land birds in the Ha'apai Group, local men across Ha'apai consistently told him that only on Tofua and Kao could lupe be found regularly and in numbers (Steadman 1998). The reason is that only surviving habitat in which lupe can breed is Tofua and Kao's tamanu and makai-dominated primary forests; a forest now confined to these islands.

Lupe is only one of a large number of birds once common throughout Ha'apai but now confined to Tofua and Kao. Several other species once common throughout Ha'apai - taiseni, kulukulu, manuma'a, fuiva, misi and fuleheu - are now largely confined to Tofua and Kao. Steadman considers this to be simply a consequence of the few people on Tofua and Kao.

On the basis of his bird observations throughout the Ha'apai Group, David Steadman has described Tofua as an 'essential island for conserving populations of birds'. Noting how much bird extinction has already has occurred in Tonga, the Steadman study considers it 'appropriate to afford protection to the forests of Tofua (and adjacent Kao) as refuges for indigenous plants and animals.' As he says, this feature of Tofua was identified in the 1980s by the German ornithologist Dieter Rinke.

Steadman's concern is the same as the Ha'apai Conservation Area Project's; to give long-term security to traditionally important biodiversity, like *lupe*, before too much more of their primary forest habitat is lost to land development.

7. Tofua and Kao as Resource Islands.

> *Kotu people often refer to agriculture on Tofua as an activity that makes the land larger -* ***fakalahi fonua*** *..... For centuries perhaps, the people of Kotu have practised an economic adaptation, which involves considerable mobility, they rely mainly on Kotu for marine resources and on Tofua for agricultural resources. Kotu and Tofua seem to represent opposites, the first being 'all lagoon' and the second 'all forest'* (Perminow, 1993).

One of the reasons that Tofua and Kao were selected as priority areas for Phase 1 of the Ha'apai Conservation Area Project is that, like Uoleva, Tatafa and Nukunamo, they are "resource islands", inhabited not by permanent settlements, but by people visiting from other islands to exploit resources now either in short supply or not present on the low islands. The Ha'apai Conservation Area Project Preparation Document proposed that the terrestrial and marine resources of such islands 'could be exploited on a sustainable basis if managed properly'(HCAP Preparation Document, 1995).

Historic evidence suggests that Tofua, if not Kao, has long been such a 'resource island', utilised by people whose permanent settlements and cultural centre are on other islands.

Tofua was in close proximity when William Bligh's *Bounty* crew mutinied in April 1789, putting Bligh and eighteen men into the *Bounty*'s launch. Seeking shelter from the south-east wind, Bligh's party headed to the island immediately, a shore-party scrambling up Tofua's steep, cliffed western side, but finding little food or water. On the second day they found a cove below Olota'ne, not safe enough to beach the launch, but where they could land through the surf. While some slept in a cave, a search party found coconuts and a little water, and made contact with some islanders who came down to the cove to trade. These people and a canoe-load of others who soon joined them, some 200 in all, identified themselves as from Nomuka, another Ha'apai island, some 80km to the south. Among them were chiefs and a young man who recognised Bligh from his visit to Nomuka twelve years earlier, with James Cook on the *Resolution*.

The same principle, that Tofua historically, served more as a resource island that Ha'apai people visited from their home islands when the need arose rather than an island with its own self-contained community, is apparent in Cook's own 1776 account. The *Resolution* had passed close enough to Tofua's southern coast that coconut palms and forest were visible. Cook, on inquiring about Tofua later on Nomuka, learned that it had a crater lake whose 's volcano was a god called Lofia, and that it was visited by islanders from the east for its black stone (Denning, 1992).

Exploitation of Tofua as a resource island today is primarily on the basis of the *'api* tax allotment land tenure system. It is clear however, from later historical accounts, during the civil war period in the early 1800s, that, as a resource island, Tofua was traditionally a revered place, endowed with resources like *kava* that were reserved for the highest, chiefly classes, or that could only be procured with chiefly authority. From William Mariner, who survived the 1806 massacre of the *Port au Prince* crew at Lifuka, and became the adopted son of the warrior king, Finau 'Ulukalala, for example, we have the record that:

> :" *Whilst Finau was yet at the Ha'apai Islands, Mr Mariner accompanied the prince to the island of Tofua, to procure iron-wood, which is found there in great abundance. The prince first obtained leave from Tuitonga (the divine chief), for this island is his property, and therefore considered sacred. Besides, it is supposed to be the residence of the sea-gods and on this account the people firmly believe that no sharks will hurt a man who is swimming near upon its coast...* (Martin, 1817; 1991).

Historically, strict systems of resource control, as well as respect of the chiefly ownership of Tofua and Kao, may have constrained over-exploitation of the vital food and material

resources that the islands contained. Such control systems would have derived from the cultural experience of resource depletion, exhaustion and collapse as Ha'apai's low islands progressively became the highly transformed cultural landscapes they are today. This experience would have been part of a wider cultural adaptation to, and alteration of the indigenous biota that the Ha'apais' first human settlers encountered.[8] While archeological evidence indicates large birds were common throughout Ha'apai at this time, it was not, other than the coconut, niu, a biota rich in reliable food plants. Prior to the era of European contact, an estimated 70 plant species were brought to Tonga as cultigens. Another 200 were accidentally introduced as weeds.

The evidence of prehistoric anthropogenic extinction of large birds that is now available for many of Ha'apai's low islands, is still lacking from Tofua. Because of Tofua's volcanism and forest growth, and the absence of substantial settlements as on islands such as Lifuka and Ha'afeva, Ha'ano and Foa, such evidence is unlikely to be obtained, unless fortuitously. But ornithological opinion is that the extinct flying species, notably the three pigeon species found in archaeological sites throughout Ha'apai, occurred on Tofua and Kao (Steadman, 1998). Each of these pigeons was notably larger than *lupe*, the Pacific Pigeon, and would have had particular ecological niches, and specific roles in seed dispersal and establishment as *lupe* does in the Tongan version of the tropical rainforest ecosystem. Similarly, each was inevitably hunted, as *lupe* was, in the late prehistoric and historic periods; appropriated by chiefs for sport and consumption(Burley, 1993).

Determining Tofua and Kao's 'community of interest' will be an important component of the Ha'apai Conservation Area project, particularly if it is concerned at the consequences for the biodiversity of Tofua and Kao of both becoming the 'increasing focus of unplanned exploitation"(HCAP Preparation Document 1995) of their resources. It is not practical however, for a botanical survey such as the present study to do any more than examine what evidence has been recorded in the literature and, on that basis, outline what Ha'apai islands appear to have an historic link to Tofua of the kind that Cook's account suggests Nomuka did in the late 18th century, and that anthropological research into oral traditions about Tofua as a resource island, suggest Kotu has in more recent times (Perminow, 1993).

James Cook's "islanders from the east" obviously refers to Ha'apai. But whether generally to all Ha'apai's inhabited islands or to one or more in particular cannot be determined in this study, on the very limited information on the cultural history of Tofua and Kao that has been available to it. Published anthropological studies that make reference to the cultural history of Tofua, less so Kao, suggest an historic phase, prior to about 1400 AD in which Tofua was relatively autonomous culturally and politically, ever since which it has close affiliation with Kotu with which a very economically important "ambilocal" relationship now exists (Perminow, 1993).

Recent work by the Canadian archaeologist, David Burley on Ha'afeva, one of a number of sites that show that the initial human colonisation of Ha'apai was a rapid one, no later than 3000 years ago, and one that occurred contemporaneously on most habitable islands, has

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[8] "Indigenous" is used here in the strict sense of being in Ha'apai naturally and not by human agency, to distinguish from "aboriginal"; those species that are in Ha'apai as a consequence, directly or indirectly, of human agency.

revealed the 'black stone' from distant Tofua or Kao, to which Cook refers, throughout the cultural sequence from the beginnings of human settlement up to the present. Burley also considers that while Tofua and Kao were never of much account as settled islands, they were certainly visited and utilised from the very beginning of human settlement of Ha'apai. Indeed it is likely they played a vital role in the initial settlement process. They would have been the 'beacon' islands that Ha'apai's first human colonists saw at a distance as they sailed east beyond Fiji, that they landed on and climbed, and saw, for the first time, the low archipelago coral islands stretched out across the eastern horizon (Shutler, Burley *et al*, 1994).

8. The Human Communities of Tofua and Kao, and the Significance of Land Tenure.

Visitors to Tofua and Kao who are unaware of the islands' human history can easily form an impression of two islands with only a slight historical human presence. The degree to which Tofua and Kao's are isolated from the nearest inhabited land, their highly indigenous, natural state and Tofua's active volcanism, makes them appear, on the face of things, to be wild islands largely free of human agency. It is for this reason that some conservation biologists have proposed Tofua and Kao as refuges for indigenous plants and wildlife (eg. Steadman 1998).

As well as containing precious indigenous biodiversity values such as its tamanu and makai primary forest, Tofua and Kao also contain some 200 accidentally-introduced weed species and some highly modified environments that reflect a long history of human settlement. occur for example. Far fewer people live on Tofua and Kao than has been the case historically, or even in recent time. A geological prospecting survey in 1987 recorded "a small population of perhaps 200 in two villages", as well as "a transient population visiting from other islands to tend gardens"(Leaman *et al*,1988). Kao was described as uninhabited, but with gardens and copra plantations of an abandoned village, Toputapu, on the southern side. The school of one of Tofua's two villages, Hokula, has been abandoned since 1987. Apart from a 10-member family group arriving towards the end of our time on Tofua and taking over the Hokula school, the Ha'apai members of the present survey expedition estimated that probably no more than 15 people were present on Tofua and Kao combined. All of them were on Tofua only temporarily, tending cultivations near the former village of Manaka.

Tofua and Kao may give the impression of once-settled, but now largely abandoned islands, But it is a misleading impression. Tofua and Kao's paucity of fresh water and level, cultivable land, their difficult accessibility from the ocean and their reputation for eruption may keep them marginal for permanent human settlement, but they continue to be integral to the micro-economy of certain Ha'apai communities. The development of conservation mechanisms within such local communities is key to the Conservation Area (CA) concept for which this ecological survey of Tofua and Kao has been undertaken.

The South Pacific Biodiversity Conservation Programme (SPBCP) has adopted the CA concept because of the extent to which most land, lagoon and reef ecosystems that are important for biodiversity are customarily owned by local communities. It recognises that these communities' needs for natural resources, and the assessment of those needs, as well as assessment of the international significance of their biodiversity assets is essential if the conservation of biodiversity in the Pacific is to be at all effective. The Conservation Area concept operates by bringing systems of Western scientific knowledge about the state of a region's plants and animals international significance alongside the customary systems of land and resource ownership and knowledge.

In Ha'apai, as in the wider Pacific, the SPBCP recognises land and resource tenure as an important factor affecting the promotion of the conservation and sustainable use of biodiversity. Land and resource tenure and the customary systems that operate them can provide considerable opportunity to conservation initiatives that incorporate them, just as they can be an obstacle to those that do not. In most Pacific island nations, ownership of land and the authority to use it is governed by families and clans who hold traditional title passed on from generation to generation; systems as complex as they are ancient. The Kingdom of Tonga is uniquely different.

The local "community" of Tofua and Kao are those families, mainly from the island of Kotu, who hold rights to *'api*, or surveyed tax allotments. On Tofua alone, more than 400 *'api* have been surveyed. These are mainly on the lower, gentler slopes where the cultivation of many crops species is possible, and on the upper slopes where most of the islands' commercial staple, *kava*, is grown. Initial inquiries, as part of the Ha'apai Conservation Area Project, into the identity and home island of Tofua's *'api* lease-holders, indicates that only 18 of these 400 have been formerly registered. These registered lease-holders come from all over Tonga, and overseas, although the majority are Ha'apai people.[9]

The Ha'apai Conservation Area Project will need to work with the leaseholders and within the *'api* system to effect the main biodiversity conservation objective proposed by this research - the protection of the tamanu and makai-dominated primary forests. The main threat to these forests is the cultivation of kava on Tofua. Kava thrives in the fertile soil that develops under primary forest of these kinds. Significant areas of tamanu forest in particular, are in zones surveyed for *'api* and thus subject to future land clearance. Furthermore, some aspects of the right (of some Kotu people) to use land on Tofua reaches back beyond the colonial era in which the *'api* system was established Some background on the *'api* system of land tenure is therefore included here.

All land in the Kingdom of Tonga is Crown Land and thus technically owned by the King. It has four categories: the Hereditary Estates of the King, the Royal Family, and the Nobles and Matapule, and Government Land. The *'api* system of surveyed tax allotments, by which each Tongan male over 16 years is entitled to an *'api kolo* (town allotment) and a larger *'api uta* (bush allotment) are granted from the two latter categories. Recent amendments to the Land Act enable a single individual to hold up to 10 *'api* for periods up to 20 years. *'Api* cannot be sold, but it can be mortgaged for a debt. *'Api* tenure has an important environmental management component in that the allotment must be maintained in a

[9] *Pers comm.* Sione Faka'osi and Mick Hortle, Ha'apai Conservation Area Project, Pangai, February, 1998.

"reasonable" state of cultivation and may not be "abandoned" for more than two years (SPREP/UNDP/GEF, 1993).

Tonga has a long history of rigid land tenure structures (Burley, 1994). The first European visitors to Tonga, just before the civil wars, were struck not only by the absence of villages, in the European sense of the term, but by the complexities of Tonga polity and the high degree of structure associated with Tongan land tenure, its elaborate system of roads bounded by well-fenced plantations (Beaglehole 1967).

The *'api* system is a modern form of these historic land tenure structures. It is the direct consequence of Tonga's 1875 Constitution which legalised the land tenure and land use systems of small family land units within defensive fortifications developed during the 1779-1852 civil wars. These land units were derived principally from land-holding chiefly lineages. They differ from the situation in lagoon and reef environments, where some authorities consider that beyond the principle that fishing rights for an area belonged to the community who lived adjacent, there may never had traditional tenure systems prior to the advent of Europeanisation.

A substantial portion of the Tofua "community" derives from the Ha'apai island Kotu (see **Fig.1**). It is apparent from recent anthropological research on Kotu that some aspects of the right to use land on Tofua reaches back beyond the colonial era in which the aggregated, village, pattern of land settlement and the modern system of tax allotment were established[10]. The first Europeans saw a dispersed pattern of settlement. It is spoken of today as *fanongonongo tokoto*. The simultaneous events of civil war and missionisation transformed *fanongonongo tokoto* this traditional Tongan pattern of settlement. The urbanised village structure that emerged from these reforms was considerably different from the earlier aggregations of a chief and followers. It was particularly so in Ha'apai which had long been somewhat divorced from the political centre of Tongatapu (Perminow 1993).

8.1 The Tofua-Kotu Land Tenure Connection

> *A large portion of Kotu's households ... . hold land on Tofua*
>
> *Very few men who have inherited the usufruct of land on Kotu and Tofua through male primogeniture (of the 1882 Land Act), actually cultivate the land or benefit from the proceeds of its cultivation*
>
> *A new[kaʻua] cultivator depends on others' support for transportation to Tofua, for gaining access to land or clearing new areas... ... .*(Perminow, 1993)

Kotu is Tonga's most densely populated island, and the only island in Ha'apai whose population is not declining. Kotu people call their relationship with Tofua and Kao, and their forests and rich soil, *fakalahi fonua* - enlargement of the land.(Perminow, 1998)

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[10] See Arne Perminow, *op cit.*

Local traditions and historical reconstruction of traditional political organisation in the Lulunga district of Ha'apai indicate that about 1400AD Tofua and Kotu were made into one single political territory.[11] At this time that has been called the Tu'i Ha'atakalaua revolution, the two islands became the estate of the chiefly title of Taufatofua (Campbell, 1989). Indications are that Tofua and Kotu were politically more autonomous before this. But it is also possible that the two islands were united under the politically autonomous leadership of the Tu'i Tofua title before being subjected together to Tongan rule.

Some of Tofua's historical significance to Kotu as a resource island may relate to bearing that the juncture in Ha'apai's political structure of the Tu'i Ha'atakalaua revolution had on *kava* cultivation. *Kava* was first domesticated in Vanuatu. It became a prized commodity of the Tongan chiefly system via a trade with the former volcanic island of Kuwae which virtually vanished in a violent eruption at the same time as the Tu'i Ha'atakalaua revolution in the mid-1400s. Legends gathered on Tikopia, a Polynesian outlier island with the Solomons part of Melanesia, by the anthropologist Raymond Firth in 1928 appear to record a trade in *kava* between Vanuatu and Tonga, terminating at this same time (Luders 1997).

This historical connection linking the mobility, still active today, between the natural resource extremes of Tofua and Kotu and the subjugation to Tongan rule has its expression in myth; how a prince of the Tongan ruling elite marries Lupe, the daughter of the Tu'i Tofua, while the son of the Tu'i Tofua jumps into the sea to become *tenifa*, a great white shark. The son that the marriage between Lupe and the Tongan prince produces becomes the first Taufatofua, whose kin-based allegiance goes to the first Tu'i Ha'atakalaua, Mo'ungamotu'a. Taufatofua, the son of the Tongan Ha'atakalaua prince and and Lupe, the daughter of the local chief, was 'sister's son' to the heir of the autonomous Tu'i Tofua title, who turned into a shark. This relates the very special, protective, relationship, in Tonga, between a nephew and his maternal uncle. For the people belonging to the territory of Taufatofua, it means that when they go to sea, as of course they have to when traveling between Kotu and Tofua, they enjoy the protection of 'their uncle', the chief among sharks. Thus Taufatofua's people may move safely between Tofua and Kotu without having to fear shark attacks. Indeed Kotu people still hold that this is the reason why people with the ancestral connection between Kotu and Tofua 'are never attacked by sharks'.

Such a myth is more than just a tale. It is the recording and transfer in allegorical code through generations of important elements of history such as the depth and strength of the Kotu-Tofua connection. Whatever the historical depth or origin of that relationship, it is essential today to the economic and demographic processes on Kotu with which the Ha'apai Conservation Area Project will have to work to achieve its objectives.

In an archipelago where modern population trends are characterised by out-movement from Ha'apai's tiny, scattered islands to Tongatapu or overseas, the relationship between people and local resources is a particularly tight one. While for all other islands of the Lulunga district, the populations has been declining in recent decades, the population of Kotu has

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[11] Much of the historical interpretation referred to in this section derives from personal communication to Geoff Park from the Norwegian anthropologist, Arne Perminow who researched the Tofua-Kotu "ambilocality", as he calls it, during periods living on Kotu from Sept. 1986 to April 1987, and from October 1991 to March 1992.

increased (Perminow, 1998). While a balance of both land and marine resource generally determine population densities in Tonga, anthropological opinion, building on detailed local knowledge of Kotu, suggests that the historical processes which have created local traditions concerning exploitation - and the sustainability - of available resources are also important(Walsh 1970).

At the time of the botanical survey of Tofua and Kao there was insufficient information available to the Ha'apai Conservation Project on the community of *'api* leaseholders and land-users on the islands. Tofua and Kao both carry the evidence of damaging land practices, notably repeated burning of kahivae, some of which burn beyond the toafa lands and into rainforest. It is likely that some of this is being undertaken by people who have neither deep ancestral ties to Tofua and Kao, nor much understanding of the damage they are causing. For the Ha'apai Conservation Project to develop a biodiversity conservation plan and more sustainable resource management, close liaison with the local community will be essential. A reliable up-to-date registry of those who have rights, ancestral or otherwise, to use Tofua and Kao land, in this regard, should be a Project priority.

9. Human Impact on the Biodiversity of Tofua and Kao.

Tofua and Kao have some of the Kingdom of Tonga's highest quality indigenous ecosystems. But they are not pristine island ecosystems only recently subject to human inhabitation. They contain many of the plants and animals with which people settled this part of the Pacific. While all evidence suggests that Tofua and Kao's limited water supplies and lack of fringing reef, restricted human settlement of kind that developed throughout Ha'apai's low, non-volcanic islands, it is also certain that people have been part of the islands' ecology for the full three millennia they have inhabited Ha'apai. This long involvement of human agency in the islands' ecosystems must be a factor in their future biodiversity conservation management.

The vegetation of large areas of Tofua and Kao is the result of human activity. The botanical survey component of this report (sec 4) distinguishes what it calls "disturbed vegetation" - *toafa* fernlands, and secondary scrub and forest - from structurally similar types of vegetation that are the product of vegetation development on new surfaces created by volcanic activity. It sets out the range of disturbed vegetation types - and their variable capacity to progress to mature forest if left alone without repeated firing. It shows secondary forest to be concentrated where agriculture has been carried out in the past. All indications are that large areas of Tofua have been deforested in recent centuries. While it is not possible to be definite, this deforestation would appear to be more the result of human agency than volcanic activity. The pattern of secondary forest would indicate that fire, lit to clear land for agriculture, has had a wide-scale impact from which Tofua's indigenous ecosystem is still recovering.

As part of this agricultural past, some 200 plant weeds and range non-native mammal species have been introduced. Many introduced animals, notably pigs, dog, and rats, have persisted and become major risks to the islands' biodiversity, in particular to any future plans to restore endangered land bird species to Tofua.

The indigenous Ha'apai biota prior to human settlement had few reliable food plants beyond niu, the coconut. From the outset, dozens of trusted cultigens were introduced. Many of them were the product of domestication in a shifting cultivation context in environments that were naturally forested. Their successful cultivation was dependent on maintaining, long term, high levels of soil fertility. In Ha'apai's low islands, that fertility was there even when the forest remained cleared away - because of the deep, nutrient- rich volcanic tephra that had been erupted over them millennia before from volcanic islands like Tofua. Some cultigens did not need a forest environment for their cultivation and have continued to be successful long after the forest has completely gone. To others, like *kava*, the forest continued to be essential.

Kava has been domesticated, originally in Vanuatu it is believed, from a natural forest understorey environment as a *forest-dearing* plant. Crop cultivation of *kava* has shifted recently from subsistence to a major cash crop, but it has not negated its need for an immediate forest-clearing environment. Kava cultivation has been increasing on Tofua at the same time as this botanical survey for the Ha'apai Conservation Area Project has identified the biodiversity significance of the same primary forest environments in which kava cultivation is undertaken. There is a point, not far in the future, at which there will be is insufficient primary forest to sustain the need for forest land in which to create new clearings for kava cultivation. If areas of tamanu primary forest are to be protected from the demands of kava cultivation, the Ha'apai Conservation Area Project and the local community will need to make the decision soon.

These three human impacts - fire, feral introduced mammals and cash-cropping of *kava* - are examined separately as they impact on the development of plans for biodiversity conservation and sustainable resource management on Tofua and Kao. They are also the subject of specific recommendations at the end of this report.

9.1 The Fire Factor

Fire is, as it has always been, an integral part of the ecology of Tofua and Kao, simply because they are volcanic islands. But as well as this fact, fire by human agency has become a major part of the islands' environment creating fernlands and shrublands where there was formerly primary forest. As a result, some of Tofua and Kao's ecosystems are as modified as anywhere in the Kingdom of Tonga. Some have been so ecologically degraded by burning that, if left free from fire, they would take centuries to repair and return to forest.

Large parts of Tofua and Kao, many of their constituent plant communities and some of the most dominant plants in those communities, are the result of repeated cycles of recovery from fires that people have lit historically to clear land. Some of the dominant plants in those fire-induced plant communities are likely to have been introduced to Tofua by people as distinct to occurring there naturally. *Toa* (*Casuarina equisetifolia*), is the prime example. It is the dominant tree of littoral forest on both islands and of most of the secondary forest and woodland vegetation. But it is probably an ancient human introduction rather than a native species.

The interaction between fire and the plants that are adapted to it is an integral part of Tofua and Kao's ecology and biodiversity, as it is elsewhere in Tonga, in the form of *toafa*. *Toafa* comprises a community of thick, high fern growth usually dominated by kahiva'e (*Dicranopteris linearis*). Tofua and Kao's *toafa* also includes the fern *Pteridium esculentum*. All areas of *toafa* would have once been rainforest, and originally cleared by the process of shifting agriculture. The same periodic burning that has kept it open, and prevented it returning to forest, has eventually so impoverished the soil that it has become virtually impossible for forest to re-establish - at least for a very long time.

Much of the recent burning by human agency of Tofua and Kao is confined to vegetation of this kind, but there are also instances where it is spreading into forest. A recent fire (**Fig. 27**), only a few months before this field survey, so large it was visible from Lifuka over 60km away, not only spread into forest, it did what few fires in recent times appear to have done; spread down into the central caldera (**Fig. 28**).

This kind of burning, which appears to be capricious rather than closely involved with agriculture, constitutes a major threat to biodiversity. In July 1997, both Tofua and Kao bore the evidence of large fires casually lit. If not prevented, fires of the scale on the 1997 fire, which actually crossed the rim of Tofua's crater rim and burn over into the steep inner, forest-covered walls of the caldera will put important Tofua's main biodiversity value at serious risk.

In environments like Tofua with vegetation of fire-prone species, fire will readily burn again in environments where it has been before. More over, as remote islands of difficult access, in an archipelago of islands with semi-subsistence economies, the fire risk is something that can only be controlled by the community that uses the islands regulating itself.

9.2 The Feral Browsing, Predator Mammal Factor

It is unfortunate that the botanical survey of Tofua and Kao for the Ha'apai Conservation Area Project did not include a survey and sampling programme to determine the presence of feral mammal species. However, in its focus on the indigenous forest areas of the two islands, it certainly became aware of the presence of feral browsing or predator mammals, the damage they are causing, and the problems they present to biodiversity conservation and the sustainability of some important ecosystems

Part of the significance of Tofua and Kao's forests as small-island Pacific examples of an ecosystem of global concern for biodiversity, namely tropical rainforest, is their evolution in a mammal-free state. As a consequence, they are vulnerable to the mammals like pig, dog and rats that have accompanied human settlement of the Pacific.

The main problem animal species for the Ha'apai Conservation Area Project on Tofua and Kao is pigs. While the impact of pigs on the indigenous vegetation is concentrated around the former village sites, it is evident that they have spread throughout the island in the long time they have been present. Pigs are integral to Ha'apai culture, like they are elsewhere in Tonga, and their removal from Tofua and Kao is unlikely to be something to which the

Figure 27. The extent of the 1997 fire on Tofua. Note the extension of the fire towards the upper slopes and crater rim.

Figure 28. The 1997 fire on Tofua burnt over the ridge and down into the crater, seriously threatening one of the best areas of makai - dominated primary forest.

islands' Kotu-based community will readily agree. On the other hand, any means to restrict pigs to the old village sites and keep them out of the rest of the islands is completely impractical.

Dogs, semi-domesticated but largely feral in their behaviour, were also observed. Rats were seen, but the expedition was not equipped to trap-sample small mammals, so the rats' species identity remains unknown. Goats were seen by some expedition members. They are said to occur throughout Tofua, but evidence of their presence is slight.

While control management of any of these feral mammal species will be difficult in isolated island environments of Tofua and Kao, leaving them to increase and spread will prohibit any biodiversity conservation plans that seek to conserve Tofua and Kao, or even parts of them, in a form that approximates their natural state before human settlement.

9.3 The *Kava* Factor

> *Kotu people first earned cash first through copra production on large volcanic Tofua. Since the early 1970s, however,* kava *has been the most important crop for Kotu people.*
>
> *Conditions on Kotu do not promote* kava *growing but most Kotu households have access to land on Tofua, an island which is recognised in Tonga for high quality* kava. (Perminow, 1998)

The Ha'apai Group was selected as the Kingdom of Tonga's Conservation Area within the South Pacific Biodiversity Conservation Programme mainly because of the increasing impact that the modern cash economy is having on terrestrial ecosystems. Tofua and Kao were selected as priority islands within the Ha'apais because although they traditionally constitute resource islands, they are both the increasing focus of unplanned exploitation of their terrestrial resources (HCAP,1995).

Many human activities on Tofua and Kao such as the lighting of fires to keep land open and the introduction of predatory and browsing mammals (dog, cat, rats, pig, goat, etc), have detrimental effects on the island's biodiversity. But the most immediately threatening human impact on the indigenous ecosystem is from the cultivation of *kava* , the domesticated varieties of *Piper methysticum.* This is largely because *kava* cultivation has the potential, if its current economic growth continues, to place an unsustainable demand on perhaps the islands' most significant biodiversity resource - its indigenous primary forests.

The production of *kava* as the major cash crop on Tofua is one of the major trends in Ha'apai agriculture in recent years. Set against the drastic fall of copra production in recent years, kava production will be a factor of major significance in the plans of the Ha'apai Conservation Area Project to develop biodiversity conservation and sustainable resource management on Tofua.

Central to *kava* cultivation as an issue with biodiversity effects is sustainability. The Ha'apai Conservation Area Project needs to consider two principles in this regard. Firstly, the cash-cropping of a plant species like *kava* must take into account interactions between the species

or stock and the living and non-living components of the ecosystem in which it is being cultivated. Secondly, the use of a wild ecosystem (which as well as sustaining people with a resource, has the capability to regulate itself and its constituent biodiversity), is a privilege, not a right and that carries obligation (Talbot, 1996).

Kava from Tofua is exported to mainly continental USA and Hawaiian markets. The very high regard for Tofua *kava* in particular derives, no doubt, from the uniqueness in the Kingdom of the "sweet" soils of the wild ecosystem in which *kava* is grown - montane tamanu primary forest. The availability of this ecosystem gives Tofua *kava* a particular quality niche, beyond Ha'apai, in the wider Tonga market. It is this quality that has led to Kotu people today considering Tofua *kava* to be, despite the arduous task of bringing a *kava* crop to market, the backbone of their cash economy.

Kava clearings are inevitably closely associated with forest. They are never found in the repeatedly-burnt open *toafa* areas. Their dependence on forest is two-fold. Firstly, the forest trees, felled and left to decay, provide the *kava* with the moist, fertile, organic soil critical to the production of a commercial crop(**Fig. 29**).. Secondly, the clearings are small and cut as narrow, rectangular strips paralleling the slope in order to use the surrounding forest as shelter and to create a local "heat trap" effect. This enhances the growth of *kava* and mulch plants alike (**Fig. 30**).

On Tofua, *kava* clearings are most abundant and extensive along the eastern flanks, particularly above and around the site of Manaka village. The great majority of the *kava* growing area is illustrated in the high-resolution aerial photograph included as **Figure 31.** The aerial photographic evidence in **Fig. 31** is consistent with the oral accounts of Kotu people that *kava* cultivation on Tofua is a currently active land use that has increased substantially in recent decades. *Kava* became the Kotu community's most important cash crop in the early 1970s.[12] Prior to that, *kava* would have been just one plant in the traditional mosaic of trees, plantains, tubers and fruit- or leaf-bearing crops intermixed with much more surrounding forests with their ferns, wild yams, nuts and fruits, and greens, and fallow areas recovering from kalokalo yam, taro and cassava cropping; the sustainable land-management system that has been called agroforestry (Perminow 1993, Thaman, 1994).

Oral historical accounts from Kotu indicate that before *kava* became a significant commodity on the national Tonga market, only the few relatively level and easily accessible parts of Tofua were cultivated. The plantations were named and, in all likelihood, had been cultivated, sustainably, for centuries. These were associated with certain patrilines and in principle were jointly cultivated by men with relatively shallow patrilines. Like Kotu, Tofua is nowadays government estate land. When *kava* became a significant cash crop, individuals from Kotu began to register their inheritable usufruct[13] of allotments by virtue of their

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[12] Perminow,*ibid*

[13] "Usufruct" is derived literally from the Latin *usus*, use; and *fructus*, fruit. It is the right of using and enjoying the produce, benefit or profits of another's property, provided that the property remains undamaged or unaltered in any way. Basically, it is a philosophical/legal ideal that you can use something and gain from it as long as future generations can use it in the way you did; a significant concept with regard to the land's and its ecosystem's and its biodiversity's continued (undamaged) sustainability.

Figure 29. Recently cleared tamanu-dominated forest, being readied for *kava* planting, above Manaka.

Figure 30. A young *kava* crop in a clearing in tamanu forest, showing the typical size oof clearings.

Figure 31. The pattern of *kava* cultivation of Tofua, in strip clearings in mainly tamanu forest on the upper slopes above Manaka village. The houses of Manaka can be seen (white) in the bottom right of the photograph. The narrow rocky ridge of the crater rim, and the burnt toafa fernland vegetation associated with it, is evident in the upper left corner.

traditional use of the land and seniority of descent.[14] Through the long-standing relationship between Kotu and Tofua, most other household heads on Kotu gained uncleared plots of Tofua land further inland and the steeper slopes of the mountain, leading to the pattern of *kava* clearings on Tofua's eastern flank today.

The cash economy led to the great majority of Tofua's *kava* being grown, not in the traditional mixed plant agroforestry system, but as a monoculture crop, with only occasional plants of other crop species. And, as the demand for cash often causes when it first takes effect in a subsistence economy, it has led to a lessening regard for the sustainability of the ecosystem that makes the crop possible. Thus in many cases where the natural forest is left standing between cultivated clearings in areas into which *kava* cultivation expanded, the forest is little more than a tall "hedge" between clearings. The land above and around Manaka is the only sector of Tofua where the ratio between the amount of land in current clearings and the amount still in forest is tight; to the extent that some parts of Tofua's eastern flanks, the situation is developing of insufficient "new" forest to provide for future *kava* cultivations.

As a consequence perhaps, *kava* clearings occur right up to the montane forest of the central crater rim, and in one area, now extend over into the upper slopes *within* the crater. The ornithologist, David Steadman stated in 1998 that he had seen no evidence of anthropogenic disturbance of forest inside the caldera rim (Steadman 1998), but aerial photographic evidence and observations during the present botanical survey in July 1997 indicated otherwise.

It is likely that this concentration of *kava* cultivation around Manaka has a considerable amount to do with minimising the difficult and dangerous task of getting the sun-dried crop down to the rock-shelf landing below Manaka village. As it is likely that the current density of *kava* clearings is a consequence of *kava*'s importance as a cash crop since the early 1970s rather than the present-day expression of a traditional land-use pattern.

A smaller area of *kava* clearings occurs on the lower western slopes of Tofua around the former village of Olota'ne, and less again near Hokula on the northern coast. On Kao, there are small areas of *kava* clearings at both the northern and southern ends, in forest associated with larger old agricultural clearings and induced *toafa*.

In 1991, as in 1986, Kotu people told the anthropologist Arne Perminow that they considered *kava* (*Piper methysticum*) to be the backbone of their economy (Perminow, 1993). Despite Tofua's rainforest being the best, and one of the last, Tongan examples of an ecosystem of global concern, and its significance for the conservation of Ha'apai's birds, it is probably safe to say that the success of any plan of the Ha'apai Conservation Area Project's

[14] And, Perminow's evidence states, their acts of 'generosity' in cash or kind towards the Governor of Ha'apai in order to press their claims.

to conserve rainforest on Tofua depends on how it negotiates with the *kava*-cultivating community.

Part of that will depend on the HCAP establishing the precise composition of the *'api* owners in the areas of Tofua and Kao where *kava* is grown. Part too, on understanding the extent to which the *kava* cultivation on Tofua might be sustainable with respect to the rainforest ecosystem in which it takes place. *Kava* depends on a particular living resource of Tofua, and one whose qualities on Tofua is found nowhere else - the rich, moist soils that develop under mid-altitude, steep-sloped, tamanu forest. As a result, the forest in parts of Tofua where this soil resource is accessible are pock-marked with the rectangular clearings of *kava* cultivation and former clearings regenerating back to forest (see **Fig. 31**).

Kava belongs to a genus of plants that has naturally occurring species throughout Tonga. It is not an indigenous Tongan plant, but an introduced cultivar of *Piper methysticum* that is believed to have been domesticated in Vanuatu. It is labour intensive to cultivate, and places high demand on the nutrient capital of the rainforest ecosystem whose trees are cleared to access the fertile topsoil in which it is grown; and on that same ecosystem's capacity to renew its nutrient capital by returning to forest once the *kava* crop is harvested.

Tofua's cash crop *kava* is cultivated very differently from the way it was traditionally. Whereas traditional *kava* cultivation comprised an opening-up of woody vegetation, either natural forest or an already-established mix of forest and domesticated trees and shrubs, and planting small groups of *kava* plants, modern cash-crop cultivation commences with the total clear-felling (**Fig. 29**) of an area some 25metres long and 5m wide. The clearing is aligned parallel to the slope, rather than up and down it, in order to minimise soil erosion during heavy rainfall periods. All woody stems are felled, and left to decay.

Kava is planted into the new forest soil two months later. They are planted so that by the time the plants are two years old, their spread prevents weed growth. (**Fig. 30**) Plants are mulched during the growth period which, on Tofua, lasts three years. At the end of the growth period the *kava* plants are completely removed and all woody and root tissue is harvested (**Fig. 32**) and sun-dried on site or nearby. The ground of the clearing is left bare after harvesting (**Fig. 34**). It is at this stage that the soil system, already depleted of nutrients by the *kava* crop, is most subject to degradation by down-slope erosion in rain events. Within a year however, the ground is covered with fern and grass growth (**Fig. 35**) into which shrub and tree species eventually establish.

Present-day *kava* cultivation follows the general technique of slash-and-burn agriculture. But there is little evidence, on Tofua, that the pattern of clearings being cut for *kava* cultivation are making sufficient allowance for the return-to-forest period. 1990 aerial photographic evidence would suggest that in the main area of kava cultivation, around and above Manaka, *kava*'s demand on the rainforest and its soil is becoming unsustainable. In other words, the intensity of clearings, (the combination of their number, the frequency at which new clearings are being cut as well as those in fallow), is outstripping the capacity of the rainforest ecosystem to provide space and fresh soil for future clearings.

At the same time, competition for land suitable for *kava* cultivation on Tofua is said to becoming intense. Some kava entepreneurs and families with *'api* on Tofua also have plans

Figure. 32 Harvesting *kava* in the clearings above Manaka. August 1997

Figure 33. *Kava* gardeners' temporary dewelling and garden, adjacent to forest clearings. Kao is visible in the background.

Figure 34. The clearings immediately after *kava* harvesting.

Figure 35. Former *kava* clearing several years after harvesting, beginning the slow return to forest.

to increase production and lodge workers on the island. This may lead to new areas of the island's primary forest being opened up. As Kotu men have recently claimed to the anthropologist Arne Perminow, there are extensive areas of forest south of Manaka in which *kava* could be grown that are neither cleared not cultivated (Perminow 1993). The botanical survey was unable to examine much of this forest, but it was assessed from the sea and is included on that basis in the vegetation map with this report.

Biodiversity conservation is a context in which the past is brought into the present. It is on this principle that the Ha'apai Conservation Area Project's definition of biodiversity embraces "the knowledge, uses, beliefs and language" of the people of Ha'apai in relation to Ha'apai's plants and animals and their ecosystems, as well as the plants, animals and ecosystems themselves. *Kava* cultivation has the potential to seriously jeopardise one of the Kingdom of Tonga's greatest terrestrial biodiversity assets - the last surviving areas of primary forest that occur mainly on Tofua, and less so Kao. In the sense that Pacific island primary forests constitute a globally significant ecosystem, this is a very high biodiversity value that needs to be seen against the traditional significance of *kava*, and deep regard for it in Tongan culture, and the high quality of Tofua's *kava* in particular (Perminow 1993). This makes the development of a *kava* cultivation plant for Tofua that takes into account the sustainability of the island's primary forests a particularly important theme of the Ha'apai Conservation Area Project.

10. Indicators for monitoring changes in biodiversity.

The above instance of the potential of *kava* cultivation to seriously jeopardise one of the Kingdom of Tonga's greatest terrestrial biodiversity assets is a good example - a prime example in fact - of why the Ha'apai Conservation Area Project needs to have the capacity to monitor future changes in Tofua and Kao's biodiversity. For this purpose, the Terms of Reference for the botanical survey included 'the identification of suitable indicators for subsequent monitoring of change at the species, community and ecosystem level'. In the process, the basis for the selection of indicators, and the manner in which they would be operationalised needed to be explained.

Once on Tofua, the survey team recognised that the identification of indicators would be dependent on, and secondary to the determination of the islands' vegetation patterns, in particular the extent of primary rainforest, and treated it accordingly. The eleven days available for fieldwork on the islands proved insufficient for even the reconnaissance botanical survey. This was so on Kao, in particular, where only two days were spent.

The Ha'apai Conservation Area Project's concern with sustainability, as well as the fact that Tofua, at least, is an active volcano whose recent eruptions have considerable expression on the pattern of plants and plant communities, means that an important component of this ecological survey therefore has been to identify some indicators of change. Such indicators need to be sufficiently sensitive and reliable and directly related to the ecosystem(s) of major

biodiversity significance and the human activities currently impacting on them. Many different kinds of ecological monitoring exist:

- mapping of changing vegetation boundaries and aerial photograph coverage
- fixed photo-points that are regularly re-photographed;
- regular sampling of populations of species sensitive to the particular change factor being monitored;
- regular sampling of fenced and unfenced plots to measure the impact of browsing animals.

The selection of indicators to identify and propose for future monitoring of ecological change was confined to mapping of changing vegetation boundaries and aerial photograph coverage. This selection was made early in the botanical survey's field programme on Tofua once:

- the nature of the range of Tofua and Kao's ecosystems, and the difficulty of accessing and reliably mapping the extent of many of them, had been seen on the ground;

- the quality of Tofua's primary rainforests in particular had been seen and their significance as a critical biodiversity value for Tonga recognised and,

- the prospects of future deliberate burning of the islands' vegetation and of future *kava* cultivation as human risks to the islands' rainforest had become apparent.

For these reasons, the botanical survey focused the attention it gave to monitoring on:

- providing for Tofua as a whole as precise as possible a delineation between the extent of primary rainforest and of secondary forest and managed land;

- the main *kava* growing areas around and above Manaka, in particular the precise extent of *kava* cultivation and the distribution of primary forest;

- the extent of the most recent (1997) fire.

The information base for the future monitoring of these indicators is two-fold: the Tofua Vegetation Map and the high-resolution colour aerial photograph of the Manaka area provided as **Figure 31** in Section 9.3. The main changes likely to be detectable in the short- and medium-term future will be changes in forest boundaries.

The Tofua Vegetation Map is attached to this report as APPENDIX 1. It is compiled from a combination of a base line map from a 1988 geological prospecting report (Leaman *et al*, 1988), on-the-ground fieldwork and photography, out-to-sea viewing and photography, and 1:10,000 aerial photography. of Unfortunately, only black and white photocopies of this photography - with subsequent low resolution of changes between forest types - were available for the field survey. The reliability of the mapping units, particularly on the

southern flanks of Tofua, is limited by the field survey being reconnaissance in nature in terms of coverage and detail of vegetation sampling.

A parallel vegetation map of Kao was not compiled for two reasons. The two days for botanical survey on Kao enabled insufficient on-the-ground observation. Furthermore, the distortion of forest boundaries in the 1:10,000 aerial photographs as a result of the great steepness of Kao volcano meant that vegetation patterns could not be reliably mapped - as the vegetation of Tofua was.

The high-resolution colour aerial photograph of the Manaka area (Fig. 31) is from a photographic run undertaken in July 1990 for the purposes of geological survey. It is at the scale of 1: 10,000.[15] The photograph provides a highly interpretive resource for both vegetation mapping and monitoring. It is sufficiently sensitive to provide a very clear picture of the pattern of impact of *kavu* cultivation with a comprehensiveness well beyond what would ever be possible from ground coverage. The different stages of cultivation and fallow, clearing by clearing, plus the rate of forest clearance and the rate of return to forest, are all clearly discernible. From it, the inroads that *kavu* cultivation has been making into the Tofua forest resource since it became a cash crop in the 1970s, could be calculated.

A very precise map base for future monitoring of the rate of forest clearance could be obtained by enlargement of the existing 1990 aerial photograph in combination with fixed-wing low-altitude photography.

The main current ecological changes on Tofua and Kao that the botanical survey suggests need to be monitored by the Ha'apai Conservation Area Project concern the extent of primary forest in the vicinity of managed land. The evidence from the botanical survey is that a probable nett decline in both forest area is occurring as a result of the human activities of cash-cropping of *kavu* and the burning of scrub and forest. Undoubtedly a parallel decline in forest health and condition is occurring, throughout both Tofua and Kao, as a result of the presence of feral pigs, goats, dogs, cats and rats.

To monitor such changes however would require the establishment and base measurement of permanent vegetation plots in the more sensitive vegetation types. This was beyond the capability of the 1997 botanical survey. However, given that Tofua and Kao's primary forests constitute some of the Kingdom of Tonga's most significant indigenous biodiversity assets, monitoring of the forests' health and condition will need to be a future component of the Ha'apai Conservation Area Project. The health of Tofua and Kao's forests and whether they are declining or increasing in area will, more than any other values, be the indicator of whether, a decade or 25 years from now, the Ha'apai Conservation Area concept is being effective on Tofua and Kao.

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[15] Copyright is with the Ministry of Lands, Survey and Natural Resources, Nuku'alofa, Tonga.

11. Management Actions resulting from the Botanical Survey

A purpose of the botanical survey report was to identify 'management actions necessary to minimise the impact of human activities on species, communities and ecosystems of particular conservation value'. This report can only facilitate a choice of such management actions by:

- drawing attention to the fact that the botanical survey for the Ha'apai Conservation Area Project has established that Tofua and Kao contain "nationally or regionally significant examples of an ecosystem of global concern", as the Category I (essential) criteria for Conservation Areas in the Pacific require;

- setting out the biodiversity values that make Tofua and Kao such special areas;

- recognising that the maintenance and enhance of these values has to achieved in a cultural environment in which the local community has had a very long history of intimate association with the same special areas as resource islands.

A major principle for deciding upon future management actions is the likelihood that, bearing volcanic eruptions large enough to eliminate all life, Tofua and Kao are fast becoming Ha'apai's last chances to conserve many of the biodiversity resources with which most of its islands were once naturally endowed. Resources, in some cases, on which Ha'apai people, like many of other Pacific Island people, rely, as they have always relied, to supplement their subsistence or semi-subsistence lifestyles. Influencing it too, is the recognition that the Kingdom of Tonga is a part of the Pacific that has "globally significant areas of biological diversity", and that birds in particular, are "an outstanding example of depletion resulting from the impact of human actions on Pacific island environments".

11. 1 Recognising that Tofua and Kao contain significant biodiversity values

Some of the earth's most critically threatened biodiversity is on islands. This is because the natural, indigenous life of many islands such as Tofua and Kao has evolved in the absence of people. But with the arrival of people and the animals and plants that came into the Pacific with them, these islands become 'extinction zones'. With have no alternative space to go to, the islands' vulnerable original species vanish from existence. It is understandable then, that biologists who have researched and monitored the patterns of deforestation and species extinctions that accompanied human settlement, island by island, across the Pacific, encounter an island like Tofua and suggest that it should be managed primarily as a refuge for native birds and the ecosystems on which they depend.

There are few islands, anywhere in the world, that are as isolated as Tofua and Kao. There are also few in which human impact is so relatively limited and the natural ecosystem so relatively intact. This is why Tofua and Kao were selected as the Kingdom of Tonga's priority areas for the South Pacific Biodiversity Conservation Programme. Neither island had been adequately surveyed biologically, although natural resource studies, in the recent past, for the government of the Kingdom of Tonga had recognised their potential for both timber exploitation and formal protection.

When the Kingdom of Tonga's forestry planners were first realising how extremely limited the nation's hardwood timber resource was, about 350 ha of "potentially exploitable" indigenous forest on Tofua was identified as the most extensive example of Tonga's natural hardwood forest (Thompson, 1976). It has been invariably referred as such in subsequent Tongan forestry studies, albeit in more recent years, that the botanical composition of Tofua's forests needed investigation before any development (Allen 1990).

The 1993 SPREP-prepared *Kingdom of Tonga: Action Strategy for Managing the Environment* considered there was little risk of this happening (SPREP, 1993). However, aware of how poorly developed Tonga's system of protected areas was compared to its marine parks and reserves, the *Strategy* identified Tofua as the area most needing consideration as Tonga's second national park, after the recently gazetted 'Eua National Park. Elsewhere the *Action Strategy* identifies both Kao and Tofua, along with Late and Niuafo'ou, as sites of prospective "Volcanic Island Reserves" . The same islands have also been proposed for gazettal by the Tongan Government as "Forest Reserves" (HCAP, 1995).

If is mainly because of the primary forest on Tofua and Kao that these islands were identified as priority islands for the Project to investigate. This ecological survey has been undertaken as a consequence of that selection as one of the initial tasks of the Ha'apai Conservation Area Project.

A primary consideration for the Conservation Areas being established in the Pacific by the South Pacific Biodiversity Conservation Programme is the inclusion within them, of special ecological and biological features. To be selected as a Conservation Area, an area must meet all criteria listed under Category I below and some of the criteria of Category II (SPREP,UNDP,GEF, 1993):

Category I, essential :

- the proposed area must contain nationally or regionally significant examples of one or more ecosystems of global conservation concern, such as tropical forests, mangroves, wetlands, lagoons and coral reefs, and must be large enough to maintain their viability.

- the project must be achievable and exhibit a high degree of commitment by landowners, residents, resource users and other potential partners in the conservation area project

- the proposed area must be sufficiently large and complex to encompass a wide range of the interactions among people and natural resources prevailing in the country.

Category II

- the proposed area should contain high levels of biological diversity and ecological complexity, represented by a number of major environments, diversity of ecosystems, and/or large numbers of genera and species of plants and animals;

- the proposed area may be important for the survival of endemic species, or of species that are rare or threatened nationally, regionally or globally; and/or

- the proposed area may be threatened by destruction, degradation or conversion.

This botanical survey of Tofua and Kao's for the Ha'apai Conservation Area Project has focused on the islands' forests in particular because they were believed to be the biodiversity features of global or Pacific regional significance. In doing so, the botanical survey has reinforced the conclusion of a recent ornithological survey of Ha'apai: that Tofua at least, is "an essential island" for biodiversity conservation because of the quality of its primary rain forests for Ha'apai's birds.(Steadman, 1998). Both studies have recognised that Tofua and Kao only have such high indigenous biodiversity values because, compared to the rest of Ha'apai, the level of human activity on them is very low.

This ecological survey has established that the forests of Tofua and Kao are some of the best remaining native vegetation in Tonga. It has done so as is part of a programme, the South Pacific Biodiversity Conservation Programme, that enables exceptional biodiversity values to be recognised and ways to conserve them found. Tofua and Kao's primary forests are now-rare examples of a distinct South Pacific island form of tropical forest, a category of global conservation concern. They are of a kind of tropical rainforest that was once spread across the Eastern Pacific. Their dominating species, tamanu (*Calophyllum neo-ebudicum)* and makai *(Canarium vitiense)*, occur, or occurred on other islands in the tropical Pacific, and their forest communities are not the only examples of their kind left in the region. But they are of a quality and extent that makes Tofua and Kao significant globally in biodiversity conservation terms.

The specific biodiversity value that this botanical survey has placed on Tofua and Kao's primary rainforests is based on the survey's botanist, A Whistler's, comparison of the forests with those elsewhere in the region. At the conclusion of his botanical description of the islands' various plant communities (Section 5), Whistler states that considers the islands' rainforests, in particular the mature makai forest inside Tofua crater, to be some of the best he has ever seen in the Pacific. Whistler's evaluation is based on an unparalleled breadth of botanical survey of the indigenous forests of the islands of the Eastern Pacific. Paralleling and reinforcing it is the recommendation of a recent land bird survey of Ha'apai, undertaken in light of the high level of extinction of birds that already has occurred in Tonga. This survey by David Steadman stated that the forests that are so crucial to Ha'apai's land birds, and which now occur only on Tofua (and Kao), should be protected as "refuges for indigenous plants and animals".(Steadman 1998).

11.2 Recognising the human community in which Tofua and Kao's significant biodiversity values need to be conserved.

Tofua may, to conservation biologists, appear to be an island remote from human settlements, largely in its original, wild forest, and thus the obvious candidate for a refuge for indigenous biodiversity(Steadman, 1998). But that ignores another reality; the ambilocality[16],

[16] "ambilocality": a functional, cultural tie to two places.

as anthropologists call it, of the people of the Ha'apai island of Kotu, Tonga's most densely populated island, and the only one in Ha'apai whose population is not declining. Kotu people call their long relationship with Tofua and Kao, and their forests and rich soil, *fakalahi fonua* - enlargement of the land.

Fakalahi fonua is a fundamental principle to which the Ha'apai Conservation Area Project will need to have regard in determining the management actions that are necessary on Tofua and Kao to minimise the impact of human activities on species, communities and ecosystems of particular conservation value. *Fakalahi fonua* notwithstanding however, the Ha'apai Conservation Area Project will also need to have regard for Tofua and Kao's exceptional biodiversity values; the primary rainforests in particular, that make them highly significant not just in the Kingdom of Tonga but, in the wider Pacific region and thus globally.

How it might be achieved, is a crucial question for the Ha'apai Conservation Area project. It raises an elemental dilemma for biodiversity conservation in Tonga: whether an area with such high conservation values should be managed as:

- first and foremost, a valuable resource for humans; whatever its values as living space for other species.; or
- first and foremost, living space for non-human beings, whatever its other values its has to humans

The first option would centre the management of Tofua instead, around ensuring the continued sustainability of the natural resources that the island has always provided, and developing management systems that simply ensure increased demand doesn't lead to unsustainable impact. 'Keeping things going" , in other words. **The second, alternative, option** would seriously consider confine all human use of Tofua to particular areas and specific uses. It would eliminate all introduced predator species such as dogs, cats and rats eliminated (SPREP/UNDP/GEF, 1993), so that bird species that formerly occurred could be re-introduced, as has reputedly been already attempted with megapodes from the Niuas.[17]

Central to the management actions of the future will be the SPBCP principle of local management for conservation areas. In keeping with it, the Ha'apai Conservation Area Project will seek to adapt to management systems which are understood and effective at the local level, and sustainable long term. This is considered to be more likely in Ha'apai than in other parts of the Kingdom of Tonga because of the relative high degree to which the Ha'apai economy relies on subsistence production that is dependent on the conservation and sustainable use of the Ha'apai islands' biodiversity (HCAP,1995). In doing so, the Ha'apai Conservation Area Project would have to recognise that the rugged physical character of Tofua and Kao makes them impractical islands to fence part off from human activities and bird predators, and develop the Ha'apai Conservation Area's theme of ecologically sustainable development in the rest.

The Conservation Area model differs from the "reserve"/ "preserve" conservation area model in industrialised countries in which people are not so dependent on their natural

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[17] The New Zealand ornithologist, Rod Hay, *pers comm,* August1997, referring to a recent introduction attempt by Dieter Rinke, of the BREHM Fund.

environment for their day-to-day survival, and where conservation efforts are focused more on protection and recreation, rather than on sustainable utilisation. The Ha'apai Conservation Area is similar to Tonga's recently designated 'Eua National Park in that it seeks to safeguard, in perpetuity, a regionally significant tropical rainforest ecosystem. But it differs in that rather than effectively excluding human use activities, it allows local customary resource management systems in ways that are ecological compatible and ensure the sustainability of the ecosystem.

For a semi-subsistence Pacific Island society like Ha'apai, biodiversity means more that what it does in industrialised countries. Whereas the predominant focus for most biodiversity conservation in industrialised countries, or motivated by them, includes uniqueness or endemism, scientific importance, significance as potential gene pools for plant and animal breeding, medicinal discoveries, etc., for most Pacific small-island societies, it is the direct basis for ecological, cultural and economic survival (Thaman, 1994b). The intimate incorporation of Tofua within the micro-economy of Kotu, for example - the large proportion of Kotu's households that hold tax allotments on Tofua - is believed to be the reason why Kotu is the most densely populated island in Tonga[18], and why in recent times Kotu's population density has increased while that of the five other islands in the Lulunga district of Ha'apai have decreased (Perminow 1993).

Nevertheless, some of the values that make Tofua and Kao exceptional places for biodiversity conservation are the direct consequence of the relative absence of people, and that they most approximate 'the natural state" of Tongan forest ecosystems as they were prior to the presence of people. Therefore, before any short term or medium term management action is undertaken on Tofua or Kao, the Ha'apai Biodiversity Conservation Project will need to decide whether its primary conservation objective with regard to these islands is:

- to restore Tonga's best prospect for conserving its natural forest in as close as possible to its natural, indigenous state, *or*

- to establish a conservation area that can function as a source of the species useful to Tongan culture, but now vanished from most islands as a result of the intensification of land use.

The Ha'apai Conservation Area Project aims to facilitate this decision. It aims to simultaneously encourage sustainable development and protect important ecosystems and species by the setting aside of certain areas as community-managed conservation areas.

11.3 The setting aside of certain areas as community-based conservation areas

[18] In the 1986 census, Kotu had 685 people per km^2, compared with the figure of 146 people per km^2 for Tonga as a whole.

There is no doubt that Tofua and Kao - Tofua in particular - have areas within them where biodiversity conservation values are significantly higher than they are elsewhere. There are islands in other parts of the world where this situation would lead to such areas being fenced off from non-indigenous browsing animals, and the rest of the island, being designated protected, and managed strictly to maintain them in their natural state, with human use by and large excluded.

Tofua and Kao are not appropriate for this kind of conservation management. Effective fencing to exclude pigs and other feral predator species could no more be realistically undertaken and maintained, cost wise, by the Ha'apai community than it could be physically on a terrain of such steep slopes and hard, rocky ground.

It would be possible, on the basis of the recent ecological survey, to broadly delineate areas of particularly high quality forest, such as the magnificent rainforests occurring within the central caldera. These forests were also those highlighted in the recent survey of Ha'apai's land birds as the best surviving forests anywhere in Ha'apai (Steadman 1998). Alternatively, the particularly ecologically diverse part of Tofua within the caldera could be delineated by the sharp topographic boundary provided by the caldera rim. As the author of the same bird survey noted, the area of Tofua within the central caldera, stands out from the rest of Tofua, as a zone where human activity is almost entirely absent. Such an area set aside from any development would have minimal impact on economic exploitation of Tofua as a resource island.

However, this report does not propose the setting aside of certain areas as community-based conservation areas. The reasons for this concern decisions that the Ha'apai Conservation Area Project has yet to resolve within the Ha'apai community, and are set out in the Recommendations, Section 12.

11.4 Achieving Sustainable Biodiversity Conservation Management on Tofua and Kao - Some Principles.

The Ha'apai Conservation Area concept defines biodiversity as " the knowledge, uses, beliefs and language that the people of Ha'apai have in relation to their ecosystems and species". It doing so it treads a fine line between:

- the concerns of Western-based, scientific conservation biology with the global and regional significance of the Pacific's myriad island ecosystems whose patterns of plants and animals occur nowhere else on earth, and

- the customary conservation mechanisms that the Pacific's many small-island indigenous cultures have developed as most appropriate to their particular form of the ownership/control/use relationship as it applies to the plants, animals and ecosystems of conservation concern.

There is a tension in that relationship in the Pacific as community-based conservation emerges as more appropriate to small-island land tenure systems than the state-owned and operated national parks and reserves approach of the industrialised West. But both

approaches, the Pacific one, centred around the local land-owning community and the latter, centred around a central government "conservation estate", have sustainability at their core .

11.4.1 The Key Principles - Sustainability and Sustainable Use

The Ha'apai Conservation Area Project's definition of biodiversity integrates nature with the culture derived from it, and sustained by it. It is about coming to terms with the past from which Ha'apai culture has derived, and being reconciled to it. It is about having such regard for Ha'apai culture and the unique life system it has become, that you endeavour not to lose those other life systems with, and from, which your culture has developed so far, but to *sustain* them somewhere. It is about *restraining* development in such a special place as Tofua.

The principle of sustainability is about "keeping things going" ; that endeavour to never lose them. A project like the Ha'apai Conservation Area Project, with its concern for the health and future of Ha'apai's natural life support systems, has to decide what "things' it wants to keep going, of all "the things" of biodiversity value it has pointed out to it by both Ha'apai people and the scientists the Project brings in to survey islands like Tofua and Kao. An essential principle in doing so is the precautionary principle of not foreclosing any options for the future - whether ecological options cut off through extinction or irreversible change, or cultural and social options cut off equally irretrievably through the denial of or discontinuance of human interactions with traditionally important natural resources.

We know that when the people of Ha'apai are asked which aspects of their cultural heritage they value most, among the most commonly mentioned are: *myths, legends, songs, dances, traditional feasts, seafoods, leis and garlands, kava, fine mats, tapa cloth, their sea-faring and fishing skills, and yam and taro gardens*. Also stressed is the importance of the unselfish sharing of these traditions with family and community (HCAP,1995.

The scientists from outside Ha'apai who are not so tied to its cultural ways and priorities are more likely to mention the Ha'apai small-island ecosystems and constituent plants and animals on which these cultural things depend on, are derived from, or (as many myths, legends, songs and dances do) focus on.

One of the common confusions about sustainability as it relates to biodiversity conservation as the Ha'apai Conservation Area Project intends, arises because of inadequate distinction between two basic types of sustainability: sustainability of the ecosystem and sustainability of a resource within it, usually a population of a species:

1. **Sustaining ecosystem function and process:** A forest ecosystem such as Tofua's rainforest can be reduced to such a size that the ecosystem no longer supports natural regeneration of the principal species. The absence of forest birds and their seed-dispersing function from the indigenous forest remnants on Tongatapu is a vivid example in Tonga.

2. **Sustaining individual resources (usually a population of a species) within the ecosystem:** A population of a species can be reduced to such low levels that it is no longer genetically viable or is at risk of no longer breeding. Conservation programmes aimed at transferring threatened bird species to predator-free islands, and building up

population numbers of such species are in this category. The gathering of seed and raising stock, in forestry nurseries, of the tree species that constituted the indigenous forest ecosystem of Tongatapu is an example.

From the various definitions of sustainability that have proliferated over the last decade or so, the key principles are:

- the viability of the biodiversity resource - the ecosystem or species - is not jeopardised;
- the resilience or capacity of the biodiversity resource to recover from perturbations is maintained;
- the interests, foreseeable needs and options of future generations are protected;
- sustainability is not confined to natural resources and ecological matters, but involves values and ethics, beliefs and attitudes, economic viability, and legal and institutional frameworks;
- sustainability involves a spectrum from scarcity to abundance, from the rare or otherwise valuable icon species to relatively common or easily grown resources; and
- the system manages an equilibrium over time, with flexibility, close monitoring and reliable indicator criteria, and the capacity to adjust and fine-tune as you proceed.

The first criterion of sustainable management of natural resources is asking whether a natural system needs to be, and should be, exploited at all. It is a corruption of the sustainability principle to suggest that it is alright, even desirable, to exploit the last few areas of a natural system as long as it is done "sustainably". Ecological sustainability includes the principle that if a resource such as a forest ecosystem is one of the last of its kind left, as in the Kingdom of Tonga, Tofua's rainforest is becoming, those who own and have responsibility for it need to very carefully consider whether it is wise to exploit it at all. Some of it certainly, an area sufficient for it to function as a forest ecosystem and be viable long term, must be kept in its natural state.

The Ha'apai Conservation Area Project is part of a regional environmental programme, the South Pacific Biodiversity Conservation Programme, that considers biodiversity to be synonymous with sustainable use. It argues from a principle that has become evident from conservation programmes in other regions of the world: if the biodiversity of Ha'apai is not conserved, or used on a sustainable basis, and if traditional management traditions, and the knowledge and language are not maintained and strengthened, all modern development will fail in the long term.(HCAP,1995).

Like all good scientific principles, sustainability is very simple as it is very complex. Pacific island cultures know about sustainability through the hard lessons of the science of long-term survival in small island ecosystems. Conservation biologists have become aware of it through the science of ecology and the principle of ecological limits that is central to it.

There is another polarity in the Ha'apai Conservation Area also; in the great ecological range in the present-day life-support systems. Tofua and Kao's life-support systems are mainly in their natural state. The life-support systems of virtually every other island, on the other hand, are in a prevailingly cultural state.

In some ways the perception of Tofua and Kao as islands in essentially their natural state with only minor areas, where human settlement has been, in a cultural state, is a superficial first impression. Every land surface is a result of volcanic activity; every plant community a derivative of that. As volcanic islands, both would have been deforested in the past by eruption events. But the extent to which they were deforested by human agency during the 3000 years of human settlement of Ha'apai, is unknown.

Most of the present-day vegetation of Tofua and Kao, it would seem, has developed from successive volcanic eruptions, with little human involvement. Only the early volcanic plant communities however, are, at the end of the 20th century, strictly as Ha'apai's first people would have experienced them. Elsewhere every plant community has been influenced in some way by the presence of people historically. In some communities such as the repeatedly burnt *toafa* and other openlands, and in formerly gardened sites, the historic human influence is obvious in the many plant species that are aboriginal introductions. In other communities such as the tamanu-dominated rainforests, it is the less-apparent absence of former species such as the two Ha'apai species of flightless megapode birds, the three large pigeons and a giant iguana and their role in ecosystem function such as seed dispersal and germination (Pregill and Dye 1989; Steadman, 1989).

Closer examination by conservation biologists aware of the trends of declining biodiversity throughout the Pacific reveal that, while Tofua and Kao can be described as containing among best examples of indigenous Tonga rainforest, some very unsustainable things are happening that, unless prevented, do not augur well long-term for the biodiversity features that make Tofua and Kao special places. Fires getting away from attempts to clear scrubland is perhaps the most serious, followed by the expansion of cash-crop *kava* cultivation into a finite area of rainforest, and the impact the two islands' populations of feral dogs, cats, rats and pigs continue to make on the indigenous ecosystem.

12. Recommendations for Short- and Medium-term Management Actions

This report presents three forms of recommendation:

1. Firstly, two primary recommendations that Tofua and Kao's forests are of such biodiversity value, in terms of their quality and international significance, that some strict protection of them is necessary as well as sustainable use of them; and, given that, the Ha'apai Conservation Area Project decide on the relative balance they wish between strict protection and sustainable use.

2. Secondly, a series of general recommendations in the form of guiding principles for sustaining Tofua and Kao's forests, their primary biodiversity asset; and

3. Thirdly, some specific short- and medium-term actions that need to be taken within the Ha'apai Conservation Area Project with respect to Tofua and Kao.

The recommendations are presented in this form because the Ha'apai Conservation Area Project is in the initial stages of a scheme to both conserve Ha'apai's biodiversity and develop Ha'apai sustainably. While it has identified Tofua and Kao as "priority island" and commissioned this ecological survey of them, it has not yet decided whether its primary emphasis on "the encouragement of sustainable development while simultaneously protecting important ecosystems and species" (HCAP,1995) relates to the Ha'apai Conservation Area as a whole, or also to the individual islands within it. Until that decision is made, few specific management actions can be taken.

It is a decision that for Tofua, is far-reaching, with respect to potential conflicts between them with respect to "sustainability". For example, Tofua's main value as perhaps Tonga's best example of the globally threatened tropical rainforest class of ecosystems is because its area of indigenous rainforest allows a greater abundance and diversity of land birds than anywhere else in Tonga. But if present trends of *kava* cultivation continue to use the same forest ecosystem on whose soil fertility it is so dependent, and no decision is made, the situation will undoubtedly arise that a choice has to be made between:

- **managing Tofua's rainforest primarily protectively**; so that it continues to be the Kingdom of Tonga's best example of a globally significant ecosystem.

- **managing Tofua's rainforest resource primarily through sustainable use**; so that it continues to sustain the production of high quality *kava* as the backbone of Kotu's cash economy.

This is not an "either/or' situation. But it is one that needs early decision as to what option predominates, and the extent to which it does.

12.1 Primary Recommendations

1. On the basis that this terrestrial ecological survey of Tofua and Kao Islands consider the islands' indigenous ecosystems, notably their forests, to be of such biodiversity value to Ha'apai and the Kingdom of Tonga, in their natural state, the islands be managed as resource islands, to maximise their forest cover and forest ecosystem function by:

- the majority portion of existing forest being strictly protected from exploitation,
- the possible setting aside from any development areas that are of high biodiversity, high quality, and can be well-defined by topographic boundaries: such as the entire area within Tofua' central caldera,
- a minority portion being utilised sustainably for cash-cropping of *kava* and or other plants important to Ha'apai culture
- areas that have been deforested by fire by human agency be encouraged to regenerate to forest.

2. That the Ha'apai Conservation Area Project in parallel:

- **Examine closely and evaluate this report's identification and description of the various biodiversity features that make Tofua and Kao "nationally or regionally significant examples of an ecosystem of global concern"**, ie the forests on which this report has focused, and the recent ornithological study of Ha'apai that has identified it as an "essential island for conserving populations of birds"(Steadman, 1998).

- **Develop an in-depth understanding of the extent to which Tofua and Kao are, and have been historically, "resource islands"**; notably the resource relationship between Kotu and Tofua, and its capability and preparedness to be guardians of the two islands' biodiversity. This is as a prelude to developing a long-term sustainable management plan for Tofua's tamanu forests etc.

- **Develop a consultative, decision-making structure within Ha'apai that can coordinate between individual *'api* owners and treat Tofua and Kao as ecosystems;** this will be necessary for decisions such as:
  - halting/limiting the burning of fernlands,
  - feral animal control that relate not to individual *'api*, but to Tofua and Kao Islands as wholes,
  - the setting aside of particularly important and topographically definable special areas for community-based conservation.

In effecting 2 and 3 above, the following questions indicate the matters that need to be established:

(a) Is the "resource island" approach to the conservation of biodiversity and sustainable development appropriate to Tofua and Kao?

(b) Should this mean that, as "resource islands", Tofua and Kao be managed according to:

- traditional Ha'apai methods of natural resource management?
- the "Western, industrial" approach of protected areas strictly reserved from human use?, or
- a combination of the two approaches?

(c) How were Tofua and Kao, and access to their resources from other more settled islands, controlled traditionally, ie. prior to the establsihment of the *'api* tax allotment system?

(d) Where in Tonga were Tofua and Kao controlled from in terms of who could procure food or materials from its forests, clear them and garden, etc.? Nuku'alofa, Kotu, Nomuka, or elsewhere?

(e) To what extent are those traditional controls still operative today in the allocation of tax allotments and maintaining authority over them?

(f) Where does control lie for what people can do on Tofua and Kao beyond the tax allotments. If someone lands on the islands and burns land beyond their api, how is that regulated, if at all?

(g) If the dogs that are roaming Tofua are to be controlled because of their impact on birds, with whom would the decision-making authority lie?

(h) On the basis that this report on terrestrial plant and ecological values considers Tofua and Kao's forests to be of international significance for their biodiversity, that another on Ha'apai's land birds considers Tofua an "essential island for conserving populations of birds", and that the islands have already been proposed as "Forest Reserves", should the Ha'apai Conservation Area Project manage their forests by:

- a form of strict protection
- sustainable use?
- a combination of strictly protected areas and sustainable use areas?

(i) If strict protection is a preferred option, for at least part of Tofua and/or Kao, does it extend to:

- excluding human use from some areas?
- eliminating feral browsing and predatory mammal species?

- re-introducing species that are considered to have once been part of the indigenous ecosystem?
- fencing?

12.2 General Recommendations for Conserving Tofua and Kao's Primary Biodiversity Assets; their forests.

Neither local traditional, nor western scientific knowledge of Tonga's rainforests is sufficient to enable us to utilise them sustainably on the cash-cropping basis they are currently being utilised for cash-crop production of *kava*. These recommendations are presented as a table of general principles (Table) with the issue of conserving the islands' forest for biodiversity in parallel with their sustainable use for *kava* cultivation in mind:

Ten guiding principles for ecologically sustainable use of forests.[19]

1. Focus on what to leave, not what to take. "What to leave" is as fully functioning an ecosystem as possible at all scales through time. Only after determining what parts of the forest need protection to achieve this goal can we determine what may be safely removed for the *kava* cultivation cycle. Understanding the historical pattern of *kava* cultivation in forests of this kind gives us important information about what must be protected and what can be removed.

2. Apply the precautionary principle to all plans and activities. If in doubt, protect indigenous ecosystem functioning, rather than the short-term profits of the annual *kava* crop.

3. Design forest plans on temporal scales of 500 years and beyond, and on large spatial scales that embrace as large a landscape as is practical on a small island, given ownership constraints. Generations of people are yet to live through and apply these long-term *forest plans*, which are different from *crop harvest plans* that the cultivators of *kava* use.

4. Respect the ecological limits a forest that has evolved in the absence of humans naturally has to human disturbance. Common ecological limits include shallow soils, or soils that take a long-time to repair their nutrient capital after the sustained disturbance of cropping them. The presence of ecological limits means that economically viable volumes of crop extracted from the ecosystem cannot be grown and cut sustainably without lasting damage to the forest and the ecosystems with which it connects.

5. Protect, maintain, and, where necessary restore natural biodiversity. This includes genetic, species, community and ecosystem diversity.

6. Protect, maintain, and, where necessary restore natural composition, structure and functions at the local forest stand and larger landscape levels. Forests such as Tofua's have natural disturbance regimes (for instance volcanic fires, cyclone windthrows, insect and disease activity). Maintaining them through time and space is the primary way to maintain natural forest landscape patterns. Forest regrowth after a *kava* cultivation clearing has been left fallow consists of young trees, and earlier successional species. Old trees and mature-age forest species are most important to maintain because they require centuries to replace.

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[19] Modified from "Ten guiding principles in the practice of ecologically responsible forest use", *Global Biodiversity* 7 1997, p.5.

7. **Protect, maintain, and, restore forest ecosystem connectivity** at all scales of time and space. Maintaining continuous links of forest, notably old growth forest, and the variety that occurs on different landform types is essential to maintaining connectivity.

8. **Diversify activities and adapt human forest uses** to the natural ecological diversity of forest as it occurs across an island.

9. **Respect and use any local culture's customary methods** that have developed local principles of sustainability through the lessons of history.

10. **Constantly review and evaluate** all forest use activities. How are we doing? How did we do? Is forest ecosystem functioning being protected, maintained and where necessary restored. Are forest uses balanced in favour of a diverse, community-based economy?

12.3 Specific Recommendations:

1. **Work with the Ha'apai community to establish an appropriate consultative and decision-making structure within Ha'apai in order that the results of this ecological survey can be set alongside local knowledge of Tofua and Kao and the customary resource management systems that relate to the two islands.**

2. **Initiate dialogue within the local Ha'apai community of people directly involved in gardening and harvesting on Tofua and Kao** in an effort to:

- stop the capricious burning of the fernlands that is preventing the fernlands from returning to forest, and in some cases, causing erosion

- ensure that, in meeting the needs of the present, the Ha'apai community's use of Tofua's rainforest for *kava* cultivation does not compromise the ability of future generations to meet their own needs[20]; in particular that it does not further use any area where the dominant trees are mature tamanu, afa, or makai.

3. **Complement the ecological survey of this report** with :

- A field study of the specific impact of kava cultivation on Tofua's rainforest: to determine firstly the rate at which the forest is being cleared, and secondly, the rate at which the forest is returning following harvesting of the *kava* crop.

[20] This recommendation is expressed in the words of the World Commission on Environment and Development's 1987 definition of *sustainable development.*

- Further ecological survey of the southern, and largely forested slopes of Tofua, and the majority of Kao, where the present survey was incomplete.

- A thorough ornithological survey to complement the recent sampling of Tofua's land birds (the Steadman survey). [Casual observations during the present ecological survey, for example included an unidentified and to-date-unrecorded petrel species heard flying inland, at night, over the crater rim in the direction of the largely inaccessible crater cliffs].

- A survey of the feral mammal populations (pig, dog, cat, rat etc) on Tofua and Kao to determine their numbers, distribution and extent to which they are harming the indigenous biodiversity values of the islands' ecosystems; together with a feasibility study of the practicality and costs of their elimination, drawing on recent experiences of feral animal eradication programmes on other small Pacific islands.

* * * * *

Figure 36. The botanical survey party of the Ha'apai Conservation Area Project leave Kao at the completion of the survey.

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APPENDICES

APPENDIX 1 : VEGETATION MAP OF TOFUA

APPENDIX 2 : TABLES FROM THE BOTANICIAL SURVEY

Table 1. Characteristics of the flora of Kao and Tofua compared to all of Tonga.
Table 2. Annotated checklist of the flora of Kao and Tofua.
Table 3. Checklist of cultivated plants found on Kao and Tofua.
Table 4. Plant communities found on Kao and Tofua.
Table 5. Survey plot data.

TABLE 1. CHARACTERISTICS OF THE FLORA OF KAO AND TOFUA COMPARED TO ALL OF TONGA

	KAO	TOFUA	TOTAL	ALL OF TONGA	PERCENT
Dicots	82	87	96	259	37%
Monocots	38	36	46	82	56%
Gymnosperms	0	1	1	2	50%
Ferns	36	49	55	90	61%
Fern allies	5	6	7	8	88%
Totals	**161**	**179**	**205**	**441**	**46%**

TABLE 2. ANNOTATED CHECKLIST OF THE FLORA OF KAO AND TOFUA.

The following annotated checklist includes the known flora of Kao and Tofua. It is arranged into five taxonomic groups: Dicots, Monocots, Gymnosperms, Ferns, and Fern Allies. Within each group the species are placed in taxonomic families, which are arranged in alphabetical, and the species are in alphabetical order within each family.

Each species entry includes the following information. Directly after the scientific name is the author of that name, and at the end of the line the Tongan name (if any), usually taken from Whistler (1991a) and verified, when possible, in the field. This is followed by a brief description of the plant, its frequency and habitat, and status (native, Polynesian introduction, or modern introduction).

The last part of each entry includes the distribution of the plants on Kao and Tofua, along with the names of the botanists who have collected the plant (Yuncker, Hotta, Scarth-Johnson, Buelow, and Whistler. The numbers following "Whistler" are voucher specimen numbers. Citations of Whistler within parentheses and are without a voucher number indicate that the species was seen there but not collected.

DICOTYLEDONS

AMARANTHACEAE

Achyranthes aspera L. tamatama

Subshrub with opposite, silvery-pubescent leaves and a terminal spike of grass-like flowers that readily adhere to clothing. Rare in coastal and disturbed habitats. Native or a Polynesian introduction. The leaves are applied to cuts to prevent infections. **KAO**: Buelow. **TOFUA**: Buelow. Not found during the present survey.

ANACARDIACEAE

Rhus taitensis Guillemin tavahi

Large forest tree with milky sap, alternate, pinnately compound leaves, panicles of tiny white flowers, and a small purple drupe. Common to dominant in secondary forest. Native. The wood is used in construction, the fruits are a favorite food of pigeons, and the bark is used in Tongan medicines for treating internal ailments. **KAO**: Yuncker, Buelow. **TOFUA**: Buelow.

APIACEAE

Centella asiatica (L.) Urban — tono

Low herb with creeping stems rooting at the nodes, alternate, kidney-shaped leaves, and tiny green, axillary flowers and fruits. Occasional in sunny places such as fernlands. Probably a Polynesian introduction. The leaves are commonly used to treat ailments of infants. **KAO**: Yuncker. **TOFUA**: Whistler 10589.

APOCYNACEAE

Alyxia stellata (Forst. f.) Roemer & Schultes — maile

Shrub with opposite or whorled, shiny green leaves, milky sap, a small white, sympetalous corolla, and a fruit that is ovoid or constricted the 2 or more seeds. Common in forests. Native. The stripped stems with leaves attached are used for making leis. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson. Whistler 10575.

Cerbera odollam Gaertn. — toto

Medium-sized tree with milky sap, glossy green leaves clustered at the ends of branches, a showy white corolla with a yellow throat, and a reddish, compressed-ovoid, mango-sized fruit. Uncommon in littoral forest. The sap is sometimes used as a purgative, and the flowers are used to make leis. Native. **KAO**: Buelow. Not found during the present survey.

Neisosperma oppositifolium (Lam.) Fosb. & Sachet — fao

Medium-sized tree with milky sap, opposite, glossy green, obovate, revolute leaves, a small white, sympetalous corolla with curved lobes, and a fibrous fruit of two spreading ovoid carpels green at maturity. Occasional in littoral forest. Native. The seeds can be eaten and were once a famine food. A solution of the wood soaked in water is sometimes used to treat hypertension and diabetes. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth- Johnson, Buelow.

ARALIACEAE

Polyscias multijuga (A. Gray) Harms — tanetane

Small tree with alternate, pinnately compound leaves, a sheathing petiole base, a large spreading panicle of small white flowers with inferior ovaries, and small fruits. Occasional in coastal forest. Native. **KAO**: Buelow. **TOFUA**: Scarth-Johnson. Whistler 10649.

ASCLEPIADACEAE

Asclepias curassavica L. — tu'ula pepe

Scarcely branching shrub with opposite leaves, milky sap, showy orange and red flowers, and a spindle-shaped follicle containing silky, windblown seeds. Uncommon as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Scarth-Johnson. Whistler 10585.

Hoya australis R. Br. lau matolu

Vine with milky sap, opposite, fleshy, oblong to elliptic leaves, long-stalked umbels of waxy white flowers marked red in the center, and a follicle containing numerous silky, windblown seeds. Occasional in sunny places. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

ASTERACEAE

Adenostemma viscosum Forst.

Large herb with opposite leaves, branching terminal panicles, heads of tiny white disc florets, and bumpy, sticky achenes with 3 terminal bristles. Rare in wet forest. Native. **KAO**: Buelow. Not found during the present survey, collected only once this century in Tonga (Buelow, in 1982).

Aster subulatus Michx.

Erect scarcely branching herb with basal leaves in a rosette, leaves on the stem alternate, tiny white florets in small heads arranged in branching panicles, and achenes bearing terminal bristles. Occasional in disturbed places such as volcanic areas. A modern introduction. **KAO**: Buelow. **TOFUA**: Whistler 10668

Bidens pilosa L. fisi'uli

Herb with pinnately lobed or compound, opposite leaves, yellow disc florets in heads arranged in panicles of heads, and small, cylindrical, barbed achenes. Occasional as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Scarth- Johnson, Buelow.

Blumea milnei Seem.

Subshrub with alternate, woolly leaves, panicles of yellow disc florets, and achenes bearing numerous terminal bristles. Rare in montane forest. Native. **KAO**: Buelow. **TOFUA**: Whistler 10642. Not previously recorded from Tonga.

Conyza bonariensis (L.) Cronq.

Erect, scarcely branching herb with hairy foliage, alternate, gray-green leaves, white disc florets in small heads on branching panicles, and plumose achenes. Common in disturbed places such as fernlands. A modern introduction. **KAO**: Yuncker. Whistler 10686. **TOFUA**: Scarth-Johnson.

Crassocephalum crepidioides (Benth.) S. Moore fisi puna

Erect herb with toothed or lobed, alternate leaves, drooping heads of disc florets red-brown at their tips, and plumed, windborne achenes. Uncommon as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Not found during the present survey.

Emilia sonchifolia (L.) DC.

Erect herb with alternate, sessile, variously shaped leaves, clasping leaf bases, a panicle of several heads of lavender disc florets, and plumed achenes. Common as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Whistler 10568.

Erechitites valerianifolia (Wolf) DC.

Tall herb with alternate, deeply pinnately lobed leaves, pink disc florets in heads arranged in terminal panicles, and plumed achenes. Uncommon in wet, disturbed places up to 1050 m elevation. A modern introduction. **KAO**: Buelow. Whistler 10709. **TOFUA**: Scarth-Johnson.

Lageniphora pumila (Forst. f.) Cheeseman

Small herb with basal leaves, ray and disc florets in a solitary, composite head atop a stalk, and small achenes. Rare at high elevations on Kao. Native. **KAO**: Buelow. Not found during the present survey and collected only once in Tonga.

Pseudelephantopus spicatus (B. Juss. ex Aubl.) C. F. Baker

Wiry, deep-rooted herb with alternate leaves and purple to white disc florets in heads arranged in a narrow, spikelike inflorescence. Uncommon as a weed of disturbed places. especially lawns. A modern introduction. **TOFUA**: Whistler 10584.

Sigesbeckia orientalis L. kakamika

Erect herb with opposite, toothed, deltoid leaves, yellow disc and ray florets in heads arranged in paniculate clusters, and sticky achenes. Uncommon in disturbed places. A Polynesian introduction. The crushed leaves are used to scent coconut oil. **KAO**: Whistler 10683. **TOFUA**: Scarth-Johnson. Whistler 10546.

Sonchus oleraceus L. longolongo'uha

Erect herb with alternate, clasping, pinnately lobed or divided leaves, spine-tipped margins, surfaces smooth, yellow disc florets in heads arranged in loose terminal clusters, and plumose achenes. Uncommon as a weed of disturbed places. Possibly a very early modern introduction. **KAO**: Buelow. Whistler 10731.

Synedrella nodiflora (L.) Gaertn.

Coarse herb with opposite leaves, yellow disc florets arranged in sessile, axillary heads, and achenes with terminal bristles. Uncommon as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Buelow. Not found during the present survey.

Vernonia cinerea (L.) Lessing fisi puna

Herb with alternate leaves, purple disc florets in heads arranged in terminal cymes, and plumose achenes. Occasional as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Whistler 10717.

Wollastonia biflora (L.) DC. ate

Subshrub with rough, ovate, opposite leaves, and yellow sunflower-like heads of yellow ray and disc florets. Common in sunny littoral areas and sometimes in fernlands. Native. The juice from the leaves is commonly used to treat cuts. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10588.

Youngia japonica (L.) DC.

Herb with lyrate, alternate leaves, yellow ray florets in small heads borne in terminal and axillary clusters, and plumose achenes. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Whistler 10634.

BARRINGTONIACEAE

Barringtonia asiatica (L.) Kurz — futu

Large, spreading tree with alternate, obovate leaves, large showy flowers bearing numerous pink and white stamens, and a large top-shaped fruit. Uncommon in littoral forest. Native. The wood is sometimes used in construction and the grated seed is used as a fish poison. **TOFUA**: Scarth-Johnson.

BORAGINACEAE

Tournefortia argentea L. f. — touhuni

Small to medium-sized tree with large, alternate, silvery leaves, scorpeoid cymes of small flowers with a white sympetalous corolla, and a small green globose fruit. Occasional in littoral forest and scrub. Native. The leaves are sometimes used in Tongan medicines. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

BRASSICACEAE

Lepidium virginicum L.

Much-branched herb with alternate, toothed leaves, small white, 4-parted flowers, and a flattened, round fruit notched at the tip. Uncommon as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Not found during the present survey.

Rorippa sarmentosa (DC.) Macbride — akataha

Small herb with alternate, deeply pinnately lobed leaves, racemes of tiny white, 4-parted flowers, and a small, narrow capsule. Uncommon in disturbed places. A Polynesian introduction or possibly native. **KAO**: Yuncker. Not found during the present survey.

BURSERACEAE

Canarium vitiense A. Gray — makai

Large tree with alternate, odd-pinnately compound leaves, 7--13 elliptic leaflets, small white flowers, and a purple, ovoid drupe. Common to dominant in primary forest. Native. The good wood is used for construction and canoes, and the fragrant sap is used to scent coconut oil. **KAO**: Yuncker. Whistler 10729. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10581. In Tonga, it is found only on Kao and Tofua.

CARICACEAE

Carica papaya L. — lesi

Small unbranched tree with alternate, palmately lobed leaves, milky sap, white, tubular male flowers in hanging racemes, solitary, axillary, white female flowers, and a large orange berry. Uncommon in disturbed places. An early modern introduction. The fruit is commonly eaten. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

CASUARINACEAE

Casuarina equisetifolia L. toa

Tall tree with leafless, pineneedle-like stems, separate male and female flowers, and a small, ovoid, conelike fruit. Common to dominant in coastal and volcanic areas. Probably a Polynesian introduction. The hard wood is used for posts, artifacts, and handicrafts, and the bark scrapings are used for treating mouth infections and stomachache. **KAO**: Whistler 10685. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

CLUSIACEAE

Calophyllum inophyllum L. feta'u

Large tree with opposite, coriaceous, finely veined, elliptic leaves, axillary racemes of flowers with 4 white sepals and 4 white petals, numerous yellow stamens, and a green, globose drupe. Occasional in littoral and coastal forest. Native. The fine wood is used for construction, slit gongs, and other things. **TOFUA**: Scarth-Johnson, Buelow.

Calophyllum neo-ebudicum Guillaumin tamanu

Large tree with opposite, coriaceous, finely veined, oblong to elliptic leaves, racemose axillary clusters of flowers with 4 white sepals and 4 white petals, numerous yellow stamens, and a purple, subglobose drupe. Common to dominant in primary and secondary forest. Native. The wood is used for construction and for making canoes, furniture, bowls (kumete), and handicrafts. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

Garcinia myrtifolia A.C. Sm. feto'umaka

Medium-sized tree with opposite, elliptic to ovate, coriaceous leaves, flowers solitary in the leaf axils, and a subglobose drupe. Occasional in primary forest. Native. The fragrant bark is used to scent coconut oil. **KAO**: Yuncker, Buelow. **TOFUA**: (Whistler).

COMBRETACEAE

Terminalia litoralis Seem. telie 'a manu

Small to medium-sized tree with alternate, obovate leaves, racemes of cream-colored flowers, and red, compress-ovoid fruits. Uncommon in forest, possibly introduced to Tofua. Native. The wood is used in construction and the bark is used in Tongan medicines. **TOFUA**: Scarth-Johnson.

CONNARACEAE

Rourea minor (Gaertn.) Alston va'a'uli

Liana with alternate, pinnately compound leaves, ovate leaflets, small white flowers, and a capsule containing red seeds. Occasional in primary and secondary forest. Native. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson, Buelow.

CONVOLVULACEAE

Ipomoea littoralis Bl.

Vine with milky sap, alternate, glabrous, heart-shaped leaves, a magenta, rotate corolla, and a subglobose, 4-seeded capsule. Occasional in sunny places. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10590.

Ipomoea macrantha R. & S. fue hina

Vine with alternate, cordate leaves, milky sap, a large, showy white, salverform corolla, and a 4-seeded capsule. Common climbing in trees in littoral and coastal forest. Native. **TOFUA**: Buelow.

Ipomoea pes-caprae (L.) R. Br. fue tahi; fue kula

Prostrate vine with red stems, alternate, round leaves notched at the tip, milky sap, and a magenta, rotate corolla. Common in sunny littoral areas. Native. **KAO**: Buelow. **TOFUA**: Scarth- Johnson, Buelow.

Operculina ventricosa (Bertero) Peter

Vine with mostly unwinged stems, cordate leaves with an acute tip, and a white rotate corolla mostly 5--10 cm. Occasional in disturbed places. Possibly native, but a recent arrival in Tonga. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow. Not found during the present survey.

CUCURBITACEAE

Cucumis melo L. 'atiu

Herbaceous vine with alternate palmately lobed leaves, tendrils, yellow, 5-lobed flowers, and a small berry with an orange pulp. Rare in disturbed places. A Polynesian introduction. The fruit of this aboriginal, small-fruited variety was probably once used for food (a miniature cantaloupe), but the plant and its uses have now been forgotten. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Momordica charantia L. lole 'ae kuma

Herbaceous vine with alternate, palmately lobed leaves, tendrils, yellow flowers on long stalks, and a lumpy, orange, spindle- shaped fruit. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Zehneria samoensis (A. Gray) Fosb. & Sachet

Herbaceous vine with thin stems, tendrils, heart-shaped leaves, small white, unisexual flowers, and a red ellipsoid berry. Uncommon in forest, mostly in sunny places. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Buelow. Not found during the present survey.

EBENACEAE

Diospyros elliptica (Forst.) P.S. Green kanume

Medium-sized tree with alternate, elliptic, coriaceous leaves, tiny white, urn-shaped, 3-lobed flowers, and a red to yellow, ellipsoid fruit. Common in coastal forest. Native. The seeds are eaten by children and have been used as a famine food, and the wood is used for posts, handicrafts, and other wooden handicrafts. **KAO**: Buelow. **TOFUA**: Buelow.

Diospyros samoensis A. Gray tutuna

Medium-sized tree with alternate, coriaceous, elliptic to ovate leaves, white, urn-shaped, 4-parted flowers, and a globose, yellowish fruit with 4 persistent, reflexed calyx lobes. Native. The seeds are eaten by land crabs and birds. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson, Buelow.

ELAEOCARPACEAE

Elaeocarpus tonganus Burk. ma'ama'alava

Medium-sized tree with alternate, ovate to elliptic leaves, a bent petiole, white flowers with numerous stamens, and a bluish, ovoid drupe. Common in forests. Native. The timber is used for posts and for making canoes. **KAO**: Buelow. **TOFUA**: Buelow. Whistler 10576.

EUPHORBIACEAE

Aleurites moluccana (L.) Willd. tuitui

Large tree with alternate, ovate or lobed, gray-green leaves, small white flowers in dense panicles, and a greenish, globose fruit containing a single, hard-shelled seed. Uncommon in forests. A Polynesian introduction. Soot from the burnt nuts is used in preparing a black tapa dye, the oil from the nuts is a major ingredient in Tongan oil, and various parts of the plant are used in Tongan medicines. **KAO**: Whistler 10695. **TOFUA**: Scarth-Johnson, Buelow.

Chamaesyce atoto (Forst. f.) Croizat

Low herb with oblong, opposite leaves, milky sap, tiny white flowers in cyathia, and a 3-lobed fruit. Occasional on coastal rocks. Native. **KAO**: Buelow. Whistler 10676.

Chamaesyce hirta (L.) Millsp. sakisi

Small succulent herb with opposite, pubescent leaves, milky sap, tiny green flowers in dense axillary cyathia, and a 3-lobed fruit. Occasional as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Hotta, Buelow.

Chamaesyce prostrata (Ait.) Small

Small, prostrate herb with purple stems, milky sap, tiny opposite leaves, inconspicuous axillary flowers in cyathia, and a 3-lobed capsule. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Euphorbia cyathophora Murray

Erect, medium-sized herb with milky sap, alternate leaves, green flowers in terminal cyathia subtended by notched, leaflike bracts red at the base, and a small 3-celled capsule. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Excoecaria agallocha L. feta'anu

Medium-sized tree with alternate elliptic to obovate leaves, milky sap, and apetalous flowers in axillary spikes or racemes. Uncommon on rocky coasts. Native. The poisonous sap can cause temporary blindness. **TOFUA**: Whistler 10579.

Glochidion ramiflorum Forst. f. malolo; masikoka

Small tree with alternate, ovate to elliptic leaves, tiny yellow, 3-lobed flowers in axillary clusters, and a wheel-shaped capsule. Common in disturbed places, and sometimes in forests. Native. The scraped bark is used in a number of Tongan medicines. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

Macaranga harveyana (Muell. Arg.) Muell. Arg. loupata

Small to medium-sized tree with alternate, ovate, peltate leaves, tiny yellow male flowers in panicles, female flowers in racemes, and soft-spiny fruits. Common in disturbed places. Native. The wood is used in light construction and the scraped bark is commonly used in Tongan medicines employed in treating internal ailments (kahi). **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Buelow.

Omalanthus nutans (Forst. f.) Pax fonua mamala

Small tree with alternate, deltoid to ovate leaves, racemes of tiny yellow male flowers, and a red, flattened, 2-lobed fruit. Occasional in disturbed places. Native. The stems are used as fence posts and yam supports, and the bark and leaves are sometimes employed in Tongan medicines. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10591.

Phyllanthus amarus Sch. & Thon.

Erect herb with spirally arranged branches, small alternate elliptic, round-tipped leaves arranged in one plane, tiny green, axillary flowers, and a tiny globose capsule. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Ricinus communis L. lepo

Shrub with large, alternate, green or purple, palmately lobed leaves, unisexual flowers with the apetalous male flowers in dense yellow heads, and a soft-spiny, 6-seeded fruit. Locally common at Hokula in disturbed places. A modern introduction. An extract of the bark is sometimes used to treat inflammations. **TOFUA**: Whistler 10656.

FABACEAE

Abrus precatorius L. matamoho

Liana with alternate, pinnately compound leaves, small oblong leaflets, pink papilionaceous flowers, and pods containing red and black seeds. Occasional in coastal areas. Native. The colorful seeds are used for decoration, but are poisonous. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson.

Canavalia rosea (Sw.) DC. heketa

Prostrate vine with alternate, trifoliate leaves, large, round- tipped leaflets, magenta papilionaceous flowers, and a flattened pod. Occasional in sunny littoral areas and sometimes weedy inland. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10577.

Canavalia sericea A. Gray — fue veli (?)

Trailing vine with alternate, trifoliate leaves, silvery leaflets, magenta papilionaceous flowers, and a flattened pod. Occasional in sunny littoral habitats. Native. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow.

Dendrolobium umbellatum (L.) Benth. — lala 'uta

Shrub with alternate, trifoliate leaves, elliptic leaflets, white papilionaceous flowers, and flattened, glabrous, jointed pods. Uncommon in sunny littoral areas. Native. **KAO**: Buelow. Not found during the present survey.

Desmodium heterocarpon (L.) DC.

Subshrub with alternate, trifoliate leaves, purple papilionaceous flowers in terminal and axillary racemes, and pubescent, 4--8- jointed, pods. Uncommon in disturbed areas and fernlands. A Polynesian introduction or possibly native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10616.

Desmodium incanum DC.

Herb with alternate, trifoliate leaves, variegated, oblong leaflets, racemes of mauve, papilionaceous flowers, and a fuzzy, jointed pod. Occasional as a weed of disturbed places. A modern introduction. **TOFUA**: (Whistler).

Desmodium triflorum (L.) DC.

Prostrate herb with small, alternate, trifoliate leaves, 1--3 axillary, purple, papilionaceous flowers, and a curved, flattened, papery, 3--6-jointed pod. Occasional in disturbed places. A modern introduction. **TOFUA**: Buelow.

Entada phaseoloides (L.) Merr. — valai; sipi; pa'anga

Liana with alternate, bipinnately compound leaves, a tendril at the leaftip, flowers in dense, axillary spikes or panicles of spikes, and a large woody pod containing several large, disc- shaped seeds. Uncommon in littoral and coastal forests. Native. The cut stems yield potable sap, and the seeds are used for decoration. **TOFUA**: Whistler 10562.

Indigofera suffruticosa Miller — 'akauveli

Spreading shrub with alternate, pinnately compound leaves, short racemes of small, salmon-colored papilionaceous flowers, and a short, curved, cylindrical pod. Locally common as a weed of disturbed places. A modern introduction. The stems are used to fashioned clothes pins and the leaves are commonly rubbed onto bee and wasp stings. **TOFUA**: Whistler 10655.

Mimosa pudica L. — mateloi

Woody herb with thorny stems, alternate, bipinnately compound leaves, palmately arranged pinnae, pink flowers in dense globose heads, and a bristly pod. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Mucuna gigantea (Willd.) DC. valai

Liana with alternate, glabrous trifoliate leaves, hanging racemes of showy, cream-colored, papilionaceous flowers, and a black, flattened pod with smooth sides. Uncommon in forests. Native. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Pueraria lobata (Willd.) Ohwi aka

Coarse, hairy vine with alternate, trifoliate leaves, lobed leaflets, violet papilionaceous flowers with a yellow blotch, and a long hairy pod. Common as a weed of disturbed places. A Polynesian introduction. The tuberous root was formerly used as a famine food. **TOFUA**: Scarth-Johnson.

Tephrosia purpurea (L.) Pers. kavahuhu

Small shrub with alternate, pinnately compound leaves, 7--15 oblanceolate leaflets notched at the tip, small, white, papilionaceous flowers, and a small, flattened-linear pod. Uncommon in sunny places. A Polynesian introduction or possibly native. An extract of the plant was formerly used as a fish poison. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson, Below. Whistler 10559.

Vigna marina (Burm.) Merr. lautolu tahi

Trailing vine with alternate, trifoliate leaves, ovate to nearly round leaflets, yellow papilionaceous flowers, and a cylindrical pod. Common in sunny littoral areas. Native. An extract of the leaves is commonly used to treat ailments thought to be caused by evil spirits (tevolo). **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow.

GESNERIACEAE

Cyrtandra samoensis A. Gray

Subshrub with large, opposite, often unequally-sided leaves, axillary clusters of white campanulate flowers, and a succulent, flesh-colored berry. Occasional in open sunny areas. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10551. Formerly known as *Cyrtandra listeri* Hemsley, which was believed to be endemic.

GOODENIACEAE

Scaevola gracilis Hook. f.

Low shrub with alternate, elliptic to lanceolate leaves, white sympetalous corollas with all the petals arranged on one side, and a white drupe. Occasional to common in volcanic areas and fernlands. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth- Johnson, Buelow. Whistler 10549. Also known as *Scaevola porrecta* A.C. Sm., which was believed to be endemic to Kao and Tofua, but is probably identical to the Kermadec species.

Scaevola taccada (Gaertn.) Roxb. ngahu

Subshrub with alternate, somewhat fleshy, spoon-shaped to nearly round leaves, a white sympetalous corolla with all the petals arranged on one side, and a white, ovoid drupe. Common in sunny littoral areas. Native. The stem bark is sometimes used in Tongan medicine to treat skin ailments. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10651.

HERNANDIACEAE

Hernandia nymphaeifolia (Presl) Kubitski — fotulona

Large tree with alternate, ovate, peltate leaves, white flowers in long-stalked axillary cymes, and a fruit surrounded by a greenish, globose vesicle open at the top. Uncommon in littoral forest. Native. The wood is used to make outrigger canoes, and the seeds are strung into leis. **TOFUA**: Whistler 10650.

LAMIACEAE

Leucas decemdentata (Forst. f.) J.E. Sm.

Small herb with opposite leaves, axillary whorls of white flowers with a 2-lipped corolla, and a fruit of 4 nutlets. Uncommon in sunny places. Native or perhaps a Polynesian introduction. **KAO**: Buelow. Not found during the present survey.

Salvia occidentalis (L.) Sw.

Herb with square stems, opposite foul-smelling leaves, tiny blue and white, bilabiate flowers in slender racemes, and a fruit of 4 nutlets. Uncommon as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Not found during the present survey.

LOGANIACEAE

Fagraea berteroana A. Gray — pua

Large tree with opposite leaves, a bump at the base of the petiole, a showy white to pale orange, tubular corolla, and a large red, many-seeded berry. Occasional in volcanic areas and cloud forest. The plant is prized as an ornamental because of its large, attractive, fragrant flowers. Native. **TOFUA**: Buelow.

Geniostoma rupestre Forst. f — te'epilo 'a Maui

Medium-sized tree with opposite leaves, axillary fascicles of tiny white flowers, and an ovoid, 2-valved capsule that splits open to expose the red seeds. Common in forests. Native. The bark is used to make a purgative. **KAO**: Yuncker. **TOFUA**: Hotta. Whistler 10555.

LYTHRACEAE

Pemphis acidula Forst. — ngingie

Shrub with alternate, oblanceolate leaves, solitary, axillary flowers with six white petals, and a campanulate capsule. Locally common on littoral rocks. Native. The wood is used for house and canoe parts, and firewood. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10578.

MALVACEAE

Hibiscus abelmoschus L.

Subshrub with alternate, palmately lobed leaves, pubescent stems and foliage, yellow, 5-parted, monadelphous flowers purple inside, and a narrowly ovoid capsule. Uncommon in disturbed places. A Polynesian introduction. **KAO**: Whistler 10681. **TOFUA**: Whistler 10635. Also known as *Abelmoschus moschatus* (L.) Medic. by some authors.

Hibiscus tiliaceus L. fau

Medium-sized, spreading tree with alternate, pubescent, heart- shaped to round leaves, axillary, showy yellow, monadelphous flowers purple at the base, and a 5-valved capsule. Common in disturbed places and secondary forest. Native. The wood is used in light construction, the bark as rough cordage and kava strainers, and various parts of the plant are used in Tongan medicine. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

Malvastrum coromandelianum (L.) Garcke te'ehoosi

Low woody herb with alternate, ovate leaves, hairy stems, pale orange, monadelphous flowers, and a wheel-shaped capsule with three bracts at its base. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Sida rhombifolia L. te'ehoosi

Subshrub with alternate, ovate leaves, pale orange, axillary, monadelphous flowers on long stalks, and a wheel-shaped capsule. Common as a weed of disturbed places. A Polynesian introduction. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

Thespesia populnea (L.) Sol. ex Correa milo

Medium-sized tree with alternate, glabrous, ovate to heart-shaped leaves, solitary, axillary, showy yellow, monadelphous flowers purple at the base, and a subglobose, non-splitting capsule. Occasional in littoral forest. Native. The attractive wood is a favorite for making handicrafts, house parts, and canoes. **KAO**: Buelow. **TOFUA**: Scarth-Johnson, Buelow.

Urena lobata L. mo'osipo Tonga

Subshrub with red stems, alternate, palmately lobed leaves, pink, 5-parted, monadelphous flowers, and a subglobose, burlike fruit. Uncommon in disturbed places. A Polynesian introduction. **KAO**: Whistler 10682. **TOFUA**: Whistler 10615.

MELASTOMATACEAE

Melastoma denticulatum Labill.

Shrub with opposite, ovate to lanceolate leaves, palmate venation and appressed pubescence, pink, 5-parted flowers with bent stamens, and a brown, appressed-hairy fruit that splits open to expose the dark red, many-seeded pulp. Common in sunny, disturbed places and fernlands. Native. **KAO**: Yuncker. Whistler 10719. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

MELIACEAE

Vavaea amicorum Benth. ahi vao

Small tree with alternate, obovate leaves clustered at the ends of the stems, axillary, long-stalked cymes of white flowers, and a globose fruit. Common in forests. Native. The wood is used for fence posts and firewood. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10583a.

MORACEAE

Ficus obliqua Forst. f. 'ovava

Large banyan with alternate, elliptic, finely veined leaves, milky sap, and an orange to red, globose, berrylike fruit. Common in forests. Native. The chewed leaves are applied to boils and the bark and leaves are used to treat inflammation. **TOFUA**: Buelow. Whistler 10648.

Ficus scabra Forst. f. masi'ata

Small to medium-sized tree with alternate, ovate to elliptic leaves, scabrous surfaces, milky sap, and a yellow to purple, globose berrylike fruit. Occasional in the littoral and inland forests. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth- Johnson, Buelow. Whistler 10661.

Ficus tinctoria Forst. f. masi'ata

Small tree with elliptic to oblong leaves having a smooth surface, milky sap, and a red to purple, globose berrylike fruit. Uncommon in forests. **KAO**: Buelow. Native. **TOFUA**: Scarth- Johnson.

MYRISTICACEAE

Myristica hypargyraea A. Gray kotone

Medium-sized tree with alternate, large, coriaceous, oblong to elliptic leaves, gray lower leaf surfaces, small, inconspicuous axillary flowers, and a large, brown ovoid fruit with a yellow aril around its single seed. Common in forests. Native. The timber is used in construction and the fruits are a food source for pigeons. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth- Johnson.

MYRTACEAE

Decaspermum fruticosum Forst. nukonuka

Shrub with opposite, lanceolate to ovate leaves, axillary, pink, 5-parted flowers with numerous stamens, and a small, globose berry. Uncommon in sunny places such as fernlands. Native. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10587.

Psidium guajava L. kuava

Small tree with opposite leaves, flowers with numerous, showy white stamens, and a yellow berry filled with many seeds in a red, fleshy pulp. Uncommon as a weed of disturbed places and sometimes cultivated. A modern introduction. **TOFUA**: Whistler 10675.

Syzygium brackenridgei (A. Gray) C. Muell. fekika vao

Medium-sized tree with opposite, oblanceolate to obovate leaves, terminal panicles of white flowers, small, persistent flower bracts, numerous stamens, and a red berry. Occasional in forests. Native. **KAO**: Buelow. **TOFUA**: Whistler 10592, 10665.

Syzygium clusiifolium (A. Gray) C. Muell. fekika vao; mafua

Medium-sized tree with opposite, elliptic, leathery leaves, many- flowered panicles arising from the trunk, small flowers, numerous white stamens, and a purple, ovoid berry. Common in coastal forests. The wood is used for posts and the fruits are eaten by pigeons. Native. **KAO**: Yuncker. Not found during the present survey (but so similar, when sterile, to the other **Syzygium** species that it may have not been recognized).

Syzygium crosbyi (Burkill) .... fekika vao

Large tree with opposite, coriaceous, elliptic leaves having a somewhat twisted mucronate tip, terminal panicles of white flowers, numerous white stamens, and a subglobose fruit. Occasional in forests. Native, endemic to Tonga. The fruits are eaten by pigeons. **KAO**: Buelow. **TOFUA**: Whistler 10571, 10666 The conversion from *Eugenia crosbyi* Burkill to **Syzygium** has not been made.

Syzygium dealatum (Burk.) A.C. Sm. mafua

Medium-sized tree with opposite, obovate, leathery leaves, somewhat 4-angled young stems, terminal panicles with somewhat flattened branch segments, white flowers, numerous white stamens, and a purple, ovoid fruit. Occasional in coastal forest. The wood is used for posts and the fruits are eaten by pigeons. Native. **KAO**: Whistler 10693. **TOFUA**: Scarth-Johnson.

NYCTAGINACEAE

Pisonia grandis R. Br. puko

Huge tree with opposite, elliptic leaves clustered at the ends of the branches, small unisexual, apetalous flowers in subumbellate clusters, and a sticky cylindrical fruits covered with rows of short spines. Uncommon in littoral forest. Native. The mediocre wood is sometimes used in light construction. **TOFUA**: (Whistler).

OLEACEAE

Jasminumsimplicifolium Forst. f. tutu'uli

Liana with thin stems, opposite, ovate to elliptic leaves, a small white salverform corolla having only two stamens, and a black, 2-lobed fruit. Common in primary and secondary forests. Native. An extract of the leaves and bark is used to treat liver ailments. **KAO**: (Whistler). **TOFUA**: Hotta, Scarth-Johnson. Whistler 10564.

OXALIDACEAE

Oxalis corniculata L. kihikihi

Small herb with basal, long-stalked, trifoliate leaves, obcordate leaflets, yellow, 5-parted flowers, and an explosive, cylindrical capsule. Uncommon as a weed of disturbed places. A Polynesian introduction. An extract of the crushed leaves are used in various children's ailments. **TOFUA**: Whistler 10674.

PASSIFLORACEAE

Passiflora aurantia Forst. f.

Herbaceous vine with alternate, ovate, 3-lobed leaves, axillary tendrils, solitary or paired showy flowers with a purplish-red corona, and a subglobose to ellipsoid berry. Uncommon in forests. Native. **KAO**: Buelow, Yuncker. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10631.

Passiflora foetida L. vaini ae kuma

Hairy herbaceous vine with alternate, palmately 3-lobed leaves, axillary tendrils, showy white and purple flowers, and a red to orange globose berry enclosed by the branching calyx lobes. Occasional as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow.

Passiflora maliformis L. vaini Tonga

Climbing vine with alternate, ovate to elliptic leaves, axillary tendrils, showy white and purple flowers, and a globose, hard- shelled fruit. Uncommon in cultivation and escaping in disturbed places. A modern introduction. The fruits are eaten. **TOFUA**: Whistler 10654.

PIPERACEAE

Macropiper puberulum Benth. kavakava'ulie

Shrub with alternate ovate to heart-shaped, palmately 5--9-veined leaves, apetalous male and female flowers in separate, axillary spikes, and tiny red drupes on the female spikes. Common in forests. Native. An extract of the leaves is used to treat skin inflammation. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth- Johnson, Hotta. Whistler 10558.

PITTOSPORACEAE

Pittosporum arborescens Rich ex A. Gray masikona

Small to medium-sized tree with alternate, oblanceolate to obovate leaves, white flowers terminal cymose clusters, and a subglobose capsule that splits along two seams to expose the orange seeds. Occasional in open areas and forests. Native. The boiled extract from the fruit is used as a fish poison. **TOFUA**: Scarth-Johnson. Whistler 10646.

PORTULACACEAE

Portulaca oleracea L. tamole

Low succulent herb with reddish stems, obovate leaves, yellow, 5- parted flowers with many stamens, and a capsule whose top splits off to release the tiny black seeds. Common as a weed of disturbed places. An early European introduction. The leaves and stems are cooked and eaten. **KAO**: Buelow. Whistler 10734. **TOFUA**: Scarth-Johnson.

Portulaca samoensis Poell. tamole?

Small, hairy, succulent herb with opposite or alternate, narrowly elliptic to lanceolate leaves, small, showy yellow, 4- or 5- parted flowers with numerous stamens, and a capsule that opens by the top splitting off. Occasional in sunny littoral areas. Native. **KAO**: (Whistler).

RHAMNACEAE

Alphitonia zizyphoides (Spreng.) A. Gray toi

Large tree with alternate, oblong to ovate leaves gray on the lower surface, small white flowers in cymes, and a globose drupe black at maturity. Common in forests. Native. The hard wood is used for making houses, canoes, and artifacts. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10645.

RUBIACEAE

Cyclophyllum barbatum (Forst. f.) A.C. Sm. & S. Darwin olamaka

Small tree or shrub with opposite, ovate to obovate leaves, interpetiolar stipules, short clusters of short white flowers, and a red, laterally compressed, obcordate fruit. Occasional in sunny places and open forest. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10563.

Guettarda speciosa L. puopua

Medium-sized tree with opposite, obovate leaves, interpetiolar stipules, white salverform flowers, and a white to brown, ovoid drupe. Common in littoral forest. Native. The wood is used in construction and for making wooden artifacts, the flowers are used to scent coconut oil, and the bark is used in Tongan medicines. **KAO**: Yuncker, Buelow. Whistler 10677. **TOFUA**: Scarth-Johnson, Buelow.

Gynochtodes epiphytica (Rech.) A.C. Sm. & S. Darwin

Liana with opposite, ovate leaves, interpetiolar stipules, axillary cymes with flowers in 3's fused at the base, a white corolla, and a black, subglobose fruit formed from 1--3 carpels. Occasional in forests. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Buelow.

Hedyotis biflora (L.) Lam.

Small herb with opposite, elliptic to ovate leaves, interpetiolar stipules, axillary panicles of 4-parted flowers, a small white, tubular corolla, and a subglobose capsule. Uncommon in littoral areas, sometimes weedy inland. Native. KAO: Buelow. Whistler 10680.

Hedyotis foetida (Forst. f.) J.E. Sm.

Woody herb with 4-angled stems, opposite, elliptic leaves, interpetiolar stipules, axillary panicles of 4-parted flowers, a white, funnel-shaped corolla, and an ovoid capsule. Common on coastal rocks. Native. **KAO**: Buelow. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Morinda citrifolia L. nonu

Shrub or small tree with opposite, elliptic to ovate leaves, interpetiolar stipules, white flowers in a globose head, and a large, fleshy, lumpy fruit. Common in coastal forest and disturbed places. Native or possibly a Polynesian introduction. The leaves, fruits, and flowers are used in many Tongan medicines, and the fruit was formerly used as a famine food. **KAO**: Whistler 10687. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

Morinda myrtifolia A. Gray

Liana with opposite, elliptic leaves, interpetiolar stipules, flowers in an axillary, stalked, globose head, corolla cream- colored, and a purple fruit formed from the fused ovaries. Occasional in forests. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson, Buelow.

Mussaenda raiateensis J. W. Moore monomono 'a hina

Shrub or small tree with opposite, ovate to elliptic leaves, interpetiolar stipules, showy yellow, tubular, 5-lobed flowers subtended by a single, showy white, leaflike sepal, and a brown ellipsoid berry. Occasional in open places and forests. Native. The bark scrapings are used to treat ailments of infants. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10644.

Neonauclea forsteri (Seem.) Merr. afa

Large tree with opposite, elliptic to obovate, paired obovate interpetiolar stipules that enclose the stem tip, terminal, globose, headlike inflorescences, white corollas, and brown, linear capsules in a globose head. Common in primary and secondary forest. Native. The wood can be used for timber. **KAO**: Buelow. **TOFUA**: Buelow.

Psychotria insularum A. Gray olavai

Shrub with opposite, elliptic leaves, interpetiolar stipules, branching, terminal inflorescences of small, white, 5-parted flowers, and a small, red, globose fruit. Common in forests. Native. **KAO**: Yuncker, Buelow. Whistler 10694. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10556.

Spermacoce assurgens Ruiz & Pavon 'aselemo

Small herb with opposite, elliptic leaves, interpetiolar stipules, and dense axillary clusters of tiny white flowers, and a capsule. Common as a weed of disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Scarth-Johnson.

Tarenna sambucina (Forst. f.) Durand ex Drake manonu

Small tree or shrub with opposite, elliptic leaves, interpetiolar stipules, flowers in widely branching cymose clusters, white to yellowish tubular corollas, and a black globose berry. Native. The scraped bark is commonly used in Tongan medicines for treating internal ailments. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10564.

RUTACEAE

Melicope retusa A. Gray

Shrub or small tree with opposite, obovate to elliptic leaves, short, many-flowered, axillary, cymose clusters of tiny white flowers, and a fruit of 1--4 follicles each containing a shiny black seed. Occasional in forests. Native. **TOFUA**: Scarth- Johnson, Buelow. Whistler 10557, 10595.

Melicope seemannii (Gillespie) A.C. Sm uhi 'ae Tofua

Shrub with opposite, trifoliate leaves, axillary inflorescences, tiny, white, 4-parted flowers, and a fruit of 1--4 follicles each containing a shiny black seed. Uncommon in sunny places. Native. **KAO**: Buelow. **TOFUA**: Hotta, Buelow. Whistler 10594.

SAPINDACEAE

Dodonaea viscosa Jacq.

Shrub with alternate, oblanceolate leaflets, panicles of small white, unisexual flowers, and a reddish, papery 2--4-winged capsule forming on the female plants. Common in fernlands. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10542.

Elattostachys falcata (Seem.) Radlkofer ngatata

Large tree with alternate, even-pinnately compound leaves, 4--6 pairs of leaflets, axillary racemes or panicles of racemes, tiny flowers with conspicuous red stamens, and an obovoid, shallowly 3-lobed capsule. Common in primary and secondary forest. Native. The wood is used for house construction, canoe building, handicrafts, and artifacts. **KAO**: Yuncker, Buelow. **TOFUA**: Buelow; Whistler 10660.

Guioa lentiscifolia Cav.

Medium-sized tree with alternate, even-pinnately compound leaves, 5--9 oblanceolate to elliptic leaflets, racemes of white flowers, red stamens, a 2--3-winged capsule, and a red aril on the seed. Occasional in forests. Native, endemic to Tonga. **KAO**: Buelow. Whistler 10696. **TOFUA**: Whistler 10573, 10653.

Pometia pinnata Forst. tava

Large tree with a buttressed trunk, large, pinnately compound leaves, toothed leaf margins, dense panicles of tiny apetalous flowers, and a large subglobose fruit. Uncommon in forests, perhaps escaped from cultivation. Probably a Polynesian introduction. The fruits (of the edible variety) are commonly eaten, and the good wood is used for timber and artifacts. **TOFUA**: Whistler 10628.

SAPOTACEAE

Planchonella grayana St. John kalaka

Large tree with alternate, elliptic to obovate leaves, milky sap, fascicled, white flowers, and a large, green to yellowish, subglobose to ellipsoid fruit containing 2 or more large, shiny ellipsoid seeds. Occasional in coastal forest. Native. The wood is occasionally used for things such as cricket bats, and for firewood. **TOFUA**: Buelow.

SCROPHULIARIACEAE

Lindernia crustacea (L.) F. Muell.

Low herb with slightly angled stems, opposite, ovate leaves, solitary, axillary flowers, a 5-lobed, 2-lipped, lavender corolla, and a small capsule. Uncommon in open places. Native. **KAO**: Yuncker. **TOFUA**: Buelow. Whistler 10666.

SOLANACEAE

Capsicum frutescens L. polo fisi

Subshrub with alternate elliptic leaves, nodding, cream-colored flowers with bright yellow stamens, and a red, ellipsoid fruit. Occasional in disturbed places, also cultivated. A modern introduction. The fruits are used as a condiment and the crushed leaves are applied to inflammation and boils. **TOFUA**: Scarth- Johnson, Buelow.

Physalis angulata L. polo pa

Erect, glabrous herb with alternate, ovate leaves, pale yellow, rotate flowers, and a globose berry enclosed within a bladder- like calyx. Occasional as a weed of disturbed places. A Polynesian introduction. The fruits are eaten by children and formerly by anyone in times of famine. **KAO**: Whistler 10725. **TOFUA**: Scarth-Johnson.

Solanum americanum Mill. polo kai

Erect herb with alternate, ovate leaves, umbels of tiny white, 5- lobed flowers, conspicuous yellow stamens, and a black, globose berry. Uncommon as a weed of disturbed places. A Polynesian introduction or indigenous. The leaves are sometimes cooked and eaten. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Solanum amicorum Benth. polo tonga

Subshrub with alternate, ovate leaves, white, rotate flowers having yellow stamens, and a red, globose berry, uncommon to occasional in littoral forest. Native. **KAO**: Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Not found during the present survey.

STERCULIACEAE

Heritiera ornithocephala Kostermans ifiifi

Large tree with alternate, oblong to ovate-elliptic leaves, a silvery-scaled lower leaf surface, apetalous, unisexual flowers purplish inside, and an apocarpus fruit of 2--5 ovoid nuts. Occasional in forests. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10570.

THYMELAEACEAE

Wikstroemia foetida (L. f.) A. Gray

Shrub with opposite, elliptic to ovate, dull-green leaves, short, a yellow, corolla-like, 4-lobed calyx, and a red ovoid drupe. Occasional in open places. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10544.

TILIACEAE

Grewia crenata (Forst.) Schinz & Guillaumin fo'ui

Small tree with alternate, ovate to lanceolate leaves, toothed leaf margins, axillary umbellate clusters of greenish-white, 5-parted flowers, numerous yellow stamens, and a black, 4-lobed drupe. Occasional in coastal areas. Native. The bark is sometimes used for cordage and (formerly) mats called sausau, and the fruits are eaten by children. **KAO**: Buelow. **TOFUA**: Scarth- Johnson. Whistler 10574.

Triumfetta rhomboidea Jacq. mo'osipo

Prostrate shrub with alternate, hairy, palmately lobed leaves, surfaces covered with stellate hairs, small yellow, 5-parted flowers in axillary fascicles, and a small bur fruit. Common in disturbed places. A modern introduction. **KAO**: Buelow. **TOFUA**: Buelow.

ULMACAEAE

Celtis harperi Horne ex Baker

Small to medium-sized tree with alternate, ovate to elliptic leaves 3-veined from the base, short axillary panicles of tiny, greenish, unisexual flowers, and a black ovoid drupe. Uncommon in forests. Native. **TOFUA**: Scarth-Johnson. Not seen by the author during the present survey, but possibly found by others in Plot 1.(Table 3).

Trema cannabina Lour. mangele

Small tree with alternate, lanceolate leaves having a rough surface and toothed margins, tiny greenish flowers in short cymose clusters, and a small red-brown to black, ovoid drupe. Uncommon in disturbed places. Native. The scraped bark is sometimes used in remedies for treating mouth infections. **KAO**: Yuncker, Buelow. **TOFUA**: Scarth-Johnson. Not found during the present survey.

URTICACEAE

Laportea interrupta (L.) Chew hongohongo

Herb with toothed, ovate, alternate leaves, mildly stinging hairs, long, loose, axillary inflorescences of greenish, apetalous flowers, and green, inconspicuous fruits. Uncommon in disturbed places, especially around habitations. A Polynesian introduction. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Maoutia australis Wedd.

Small tree with alternate, ovate to elliptic leaves 3-veined from the base, toothed margins, white lower leaf surface, dense panicles of tiny, apetalous, unisexual flowers, and tiny red achenes. Occasional in open volcanic areas. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10552.

Pipturus argenteus (Forst. f.) Wedd. 'olonga

Small tree with alternate, ovate leaves 3-veined from the base, a gray lower surface, apetalous, unisexual, greenish flowers in globose clusters on branching axillary panicles, and a succulent, white receptacle with the achenes embedded in it. Occasional in disturbed places and secondary forest. Native. The bark fibers were formerly used for making fishing lines and nets. **KAO**: Yuncker. Whistler 10716. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10669.

VERBENACEAE

Clerodendrum inerme (L.) Gaertn. tutu hina; tutu tahi

Scandent shrub with opposite, ovate to elliptic leaves, showy white salverform flowers having red, long-protruding stamens, and an obovoid, 4-lobed fruit splitting into nutlets. Occasional in littoral areas. Native. **TOFUA**: Scarth-Johnson, Buelow. Whistler 10652.

Faradaya amicorum (Seem.) Seem. kili?; fufula?

Liana with opposite, ovate to oblong leaves, dense branching panicles, a white, trumpet-shaped, 4-lobed corolla, and 1 or 2 curved-ovoid, red drupes. Common in forests. Native. The bark is used in Tongan medicines to treat stomachache and cancer. **KAO**: Buelow. **TOFUA**: Hotta, Buelow. Whistler 10583.

Premna serratifolia L. volovalo

Shrub or small tree with opposite, ovate to elliptic leaves, tiny 4-parted, white flowers in dense, flat-topped panicles, and a small, black, ovoid drupe. Occasional in sunny places. Native. The leaves are used in Tongan medicines. **KAO**: Yuncker, Buelow. Whistler 10688. **TOFUA**: Scarth-Johnson, Buelow.

Stachytarpheta urticaefolia (Salisb.) Sims hiku 'i kuma

Subshrub with coarse, opposite leaves, dentate leaf margins, narrow spikes of purple, sympetalous flowers, and a small 2- seeded capsule. Common as a weed of disturbed places. A modern introduction. **TOFUA**: Whistler 10657.

MONOCOTYLEDONS

AGAVACEAE

Cordyline fruticosa (L.) Chev. si

Shrub with parallel-veined, lanceolate leaves, white to pink flowers in dense panicles, and a small red, globose berry. Common in disturbed places and forests. Probably a Polynesian introduction. The leaves are used for making dance skirts, wrapping food for cooking, and in Tongan medicine, and the roots were formerly baked and eaten. **KAO**: Yuncker. **TOFUA**: Scarth- Johnson, Buelow.

ARACEAE

Amorphophallus paeoniifolius (Dennst.) Nicolson teve

Large stemless herb with an underground corm, large, erect, palmately veined leaves and tiny unisexual flowers on a large spadix enclosed within a campanulate spathe, appearing once a year.

Rare in disturbed places. A Polynesian introduction. The root was formerly used as a famine food. **TOFUA**: Scarth-Johnson. Not found during present survey.

ARECACEAE

Cocos nucifera L. niu

Tall palm with large, pinnately compound fronds, unisexual flowers in large panicles, and a large, thick-husked nut. Common in plantations and secondary forest. Native. Various parts of the tree are used for food, timber, thatch, baskets, and many other things. **KAO**: (Whistler). **TOFUA**: (Whistler).

COMMELINACEAE

Commelina benghalensis L. kaningi

Low, somewhat fleshy, pubescent herb rooting at the nodes, with alternate, ovate leaves and a folded inflorescence bract containing small blue, 3-parted flowers. Uncommon as a weed of disturbed and cultivated areas. A modern introduction. **TOFUA**: Scarth-Johnson. Not found during the present survey.

CYPERACEAE

Cyperus compressus L.

Small sedge with basal linear leaves, a terminal cluster of green, flattened-lanceolate spikelets subtended by several linear bracts. Uncommon in disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Eleocharis geniculata (L.) Roemer & Schultes

Small, leafless, clump-forming sedge with narrow, cylindrical, septate stems and brown spikelets in a compact terminal spike. Rare in wet places. Native. **KAO**: Yuncker. Not found during the present survey.

Fimbristylis cymosa R. Br. pakopako

Small, clump-forming sedge with linear leaves and brown spikelets in a head or panicle of heads. Occasional on rocky shores. Native. **KAO**: (Whistler).

Fimbristylis dichotoma (L.) Vahl

Medium-sized tufted sedge with short basal, linear leaves, long narrow stems, and terminal umbellate clusters of brown ovoid spikelets on unequal rays. Common as a weed in disturbed places. Probably a modern introduction. **KAO**: Yuncker, Buelow. Whistler 10690. **TOFUA**: Whistler 10548.

Mariscus cyperinus (Retz.) Vahl

Medium-sized tufted sedge with triangular stems, linear leaves shorter than the stems, and green to brown spikelets in compact, headlike terminal clusters subtended by involucral bracts. Occasional as a weed of disturbed places. Possibly a modern introduction. **KAO**: Buelow. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10566. This species is easily confused with **Mariscus sumatrensis**.

Mariscus javanicus (Houtt.) Merr. & Metcalfe mahelehele

Medium-sized to large sedge with sharp-edged, gray-green, linear leaves longer than the stem and brown spikelets arranged in a large terminal panicle. Uncommon in sunny littoral and coastal areas. Native. **KAO**: Buelow. **TOFUA**: Whistler 10569.

Mariscus seemannanius (Boeck.) Palla

Large coarse sedge with basal linear leaves and sessile, brown spikelets on spreading rays in terminal umbellate clusters. Rare in forests. Native. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Mariscus sumatrensis (Boeck.) Raynal

Medium-sized sedge with triangular stems, linear leaves, and cylindrical spikes of lanceolate spikelets subtended by involucral bracts. Occasional as a weed of disturbed places and sunny forests. Native or a Polynesian introduction. **KAO**: Buelow. Whistler 10689. **TOFUA**: Scarth-Johnson, Hotta. Whistler 10550.

Pycreus polystachyos (Rottb.) Beauv.

Medium-sized sedge with linear leaves shorter than the stem and brown, linear-lanceolate spikelets in compact umbellate inflorescences. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Whistler 10633.

Scleria lithosperma (L.) Swartz

Narrow-leaved, grass-like sedge with a narrow, loose, terminal inflorescence with spikelets producing small, hard, white globose seeds. Occasional in forests, especially along trails. Native. **KAO**: Buelow. Whistler 10733. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

Scleria polycarpa Boeck. mahelehele

Medium-sized sedge with linear, sharp-edged leaves and a branching, terminal inflorescence with spikelets producing a hard, globose, white seed. Occasional in sunny disturbed places. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow.

DIOSCOREACEAE

Dioscorea bulbifera L. hoi

Climbing weedy vine with alternate, heart-shaped leaves, axillary bulbils, and panicles of tiny inconspicuous flowers. Common as a weed of disturbed places. A Polynesian introduction. The aerial and underground tubers were formerly used as a famine food. **TOFUA**: Scarth-Johnson, Buelow.

Dioscorea pentaphylla L. lena

Climbing weedy vine with alternate, palmately 3--5 lobed leaves, and panicles of tiny flowers. Uncommon in disturbed places. A Polynesian introduction. The tubers were formerly used as a famine food. **TOFUA**: Buelow. Not found during the present survey.

LILIACEAE

Dianella intermedia Endl. afuafu

Erect rhizome-forming herb with distichous, swordlike leaves and blue to white flowers in loose terminal panicles. Occasional in coastal areas and in fernlands. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10453.

ORCHIDACEAE

Acanthephippium papuanum Schlechter

Large terrestrial orchid with a fleshy pseudobulb, large plicate leaves, and axillary racemes of large, yellowish white to pink flowers. Native. **TOFUA**: Buelow. Not found during the present survey.

Appendicula reflexa Bl.

Small epiphytic orchid with oblong leaves arranged in one plane and short axillary spikes of white flowers hanging from the lower surface of the plant. Occasional in forests. Native. **KAO**: Yuncker, Buelow, Whistler 10700. **TOFUA**: Hotta, Buelow. Whistler 10607.

Bulbophyllum cf. **membranaceum** Teijsm. & Binnend.

Small, creeping epiphytic orchid with pseudobulbs, narrowly lanceolate leaves, and solitary, long-stalked, purple flowers. Locally common in forests. Native. **KAO**: Yuncker, Buelow. Whistler 10703. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10612.

Bulbophyllum pachyanthum Schltr.

Medium-sized, creeping, epiphytic orchid with pseudobulbs producing several thick leaves, and several large, yellow and red flowers atop a long stalk. Uncommon in forests. Native. **KAO**: Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Whistler 10641.

Calanthe hololeuca Reichenb. f.
Medium-sized ground orchid with large plicate leaves and leafless terminal racemes bearing many showy white, spurred flowers. Occasional in forests. Native. **KAO**: Buelow. **TOFUA**: Hotta, Buelow. Whistler 10598.

Dendrobium calcaratum A. Rich.

Long-stemmed, epiphytic orchid with striate stems, leathery lanceolate leaves, and axillary clusters of pale orange flowers. Common in mature forests. Native. **KAO**: Buelow. **TOFUA**: Hotta, Buelow.

Dendrobium platygastrum Reichenb. f.

Medium-sized epiphytic orchid with thick, flattened stems, deciduous ovate leaves, and 2 or 3, white to pink flowers in terminal racemes. Occasional in forests. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta. Whistler 10618.

Erythrodes oxyglossa Schltr.

Small terrestrial orchid with lanceolate leaves with an acute tip, pubescent inflorescences, and a few pinkish flowers in a terminal raceme. Occasional in forests. Native. **KAO**: Buelow. **TOFUA**: Buelow. Whistler 10602.

Erythrodes parvula Kores

Small terrestrial orchid with lanceolate leaves with a rounded tip, pubescent inflorescences with 2 or 3 lanceolate bracts on the penduncle, and several pinkish flowers in a terminal raceme. Uncommon in forests. Native. **TOFUA**: Buelow. Whistler 10603.

Eulophia nuda Lindl. ex Wallich

Medium-sized terrestrial orchid with plicate leaves, showy white flowers in a scapose raceme, and a ribbed capsule. Uncommon in forests. Native. **KAO**: Buelow. **TOFUA**: Buelow. Not found during the present survey.

Eulophia pulchra (Thou.) Lindl.

Medium-sized terrestrial orchid with plicate leaves and a scapose raceme of yellow and red flowers. Rare in forests. Native. **KAO**: Buelow. Not found during the present survey.

Geodorum densiflorum (Lam.) Schltr.

Large-leaved terrestrial orchid with plicate leaves, showy pink flowers atop a short, drooping, scapose spike, and large, ribbed capsules. Occasional in sunny places. Native. **KAO**: Buelow. Whistler 10692. **TOFUA**: Buelow.

Hetaeria oblongfolia Bl.
Small terrestrial orchid with ovate leaves, a terminal raceme having a pubescent stalk with 4--6 lanceolate bracts, and many small white flowers. Native. **KAO**: Buelow. Not found during the present survey.

Liparis disepala Reichenb. f.

Small solitary, terrestrial orchid with clasping lanceolate leaves, a terminal, bracteate raceme, and red to yellowish brown flowers. Occasional in fernlands. Native. **KAO**: Whistler 10691. **TOFUA**: Buelow. Whistler 10614.

Liparis elegans Lindl.

Epiphytic orchid with a fleshy erect stem and a terminal raceme of many small, cream-colored flowers. Occasional in forests. Native. **KAO**: Buelow. Whistler 10721. **TOFUA**: Hotta, Buelow. Whistler 10606.

Liparis laydardii F. Muell.

Small epiphytic orchid with ovate leaves, a terminal raceme up to 30 cm long, and showy purplish flowers. Rare in forests. Native. **KAO**: Buelow. Whistler 10713. **TOFUA**: Buelow. Whistler 10600.

Malaxis brevidentata (Rolfe) C. Schweinf.

Small terrestrial orchid with ovate, plicate leaves and a terminal raceme of small, white, short-spurred flowers. Uncommon in forests. Native. **KAO**: Yuncker, Buelow. Whistler 10701. **TOFUA**: Hotta, Buelow. Whistler 10639.

Malaxis resupinata (Forst.) Kuntze

Medium-sized terrestrial orchid with relatively large, plicate, ovate leaves and a terminal raceme of small, short-spurred, maroon flowers. Occasional in forests and high-elevation fernlands. Native. **TOFUA**: Buelow. Not found during the present survey.

Oberonia equitans (Forst. f.) Mutel

Small, erect, laterally compressed, epiphytic orchid with distichous leaves and a terminal raceme of tiny white flowers. **TOFUA**: Buelow.

Peristylus cf. **novoebarum** F. v. Mueller

Small terrestrial orchid with a ovate leaves and a long, thin raceme of small, greenish flowers having a small subglobose spur. Uncommon in forests. Native. **KAO**: Buelow. Not found during the present survey.

Phaius cf. **flavus** Bl.
Large terrestrial orchid with large, ovate, plicate leaves and a terminal raceme of large, showy yellow flowers marked with purple lines. Uncommon in forests. Native. **TOFUA**: Buelow. Whistler 10599.

Phaius terrestris (L.) Ormerod

Large terrestrial orchid with a short distinct stem, large plicate leaves, and a terminal raceme of showy white flowers with yellow in the center. Uncommon in forests. Native. **KAO**: Buelow. Not found during the present survey.

Phaius tankervilleae (Banks ex L'Her.) Bl.

Large terrestrial orchid with large basal, plicate leaves and a terminal raceme of large, showy lavender, white, and brownish flowers. Uncommon in forests. Native. **KAO**: Buelow. **TOFUA**: Hotta. Whistler 10621.

Phreatia micrantha (A. Rich.) Schltr.

Medium-sized, laterally compressed, epiphytic orchid with long- stalked axillary racemes of tiny white flowers. Occasional in forests. Native. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth- Johnson.

Spathoglottis plicata Bl.

Large terrestrial orchid with large, basal, plicate leaves and a tall raceme of large, showy, pink flowers with yellow in the center. Occasional in disturbed places. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson.

Spiranthes sinensis (Pers.) Ames

Small, narrow terrestrial orchid with linear leaves and a twisted, terminal spike of tiny pink flowers. Uncommon in open areas. Native. **TOFUA**: Hotta. Whistler 10623.

Taeniophyllum fasciola (Forst. f.) Reichenb. f.

Leafless, epiphytic orchid with flattened, photosynthetic roots, and tiny white flowers in a thin, few-flowered raceme. Uncommon in littoral and inland forests. Native. **KAO**: Buelow. Not found during the present survey.

Zeuxine stenophylla (Reichenb.) Bentham & Hook. f. ex Drake.

Small terrestrial orchid with ovate leaves and a terminal raceme of small white flowers having rounded tepals. Uncommon in forests. Native. **KAO**: Buelow. Not found during the present survey.

PANDANACEAE

Pandanus tectorius Parkinson — fafa

Medium-sized tree with long, thorny leaves and stems, prop-roots, white bracted male inflorescences, and a large, woody, globose, syncarp fruit. Common in littoral forest. Native. The leaves, especially that of select varieties, are commonly woven into mats. **KAO**: (Whistler). **TOFUA**: (Whistler).

Pandanus whitmeeanus Mart. — paongo

Medium-sized tree with long, relative wide, thorny leaves, white-bracted male inflorescences, and a large, woody, globose syncarp. Cultivated but occasional in secondary forest. Probably a Polynesian introduction. The leaves are commonly woven into coarse mats. **KAO**: (Whistler). **TOFUA**: (Whistler).

POACEAE

Brachiaria subquadripara (Trin.) Hitchc.

Low creeping grass with linear leaves, several spreading racemes, and solitary spikelets in two rows on one side of the angular rachis. Locally common as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Whistler 10586.

Cenchrus calyculatus Cav. — hefa

Medium-sized grass with a long, terminal spike bearing bur-like spikelets. Rare in sunny coastal places. Native. **TOFUA**: Scarth-Johnson. Not found during the present survey.

Cenchrus echinatus L.

Medium-sized grass with a narrow spike bearing sharp-spined burs. Locally common in disturbed places, especially in coastal areas. A modern introduction. **TOFUA**: Buelow.

Centosteca lappacea (L.) Desv. — mohuku 'apopoa

Medium-sized grass with bamboo-like leaves, a terminal panicle with several slender spreading branches, and awnless spikelets. Common in disturbed forest and along forest trails. Probably a Polynesian introduction. **TOFUA**: Hotta. Not found the present survey.

Chloris divaricata R. Br.

Creeping grass with tufted stems, linear leaves, a panicle of digitate racemes, and closely packed, awned, green spikelets. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Chrysopogon aciculatus (Retz.) Trin. mata pekepeka

Small prostrate grass with stems rooting at lower nodes, a short, erect panicle with filiform branches, and purple, awned spikelets. Common in sunny disturbed places and lawns. A Polynesian introduction. **KAO:** (Whistler). **TOFUA**: Scarth- Johnson.

Cyrtococcum oxyphyllum (Hochst. ex Steudel) Stapf

Small grass rooting at the lower nodes, with a panicle of fine branches appressed to the panicle axils and small, unawned spikelets. Occasional in forests. Native or possibly a Polynesian introduction. **KAO**: Whistler 10724. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10583.

Dactyloctenium aegyptium (L.) Beauv.

Small grass with creeping stems, several digitate spikes atop the rachis, densely packed, short-awned spikelets, and the seeds falling free of them. Uncommon in disturbed coastal areas. A modern introduction. **TOFUA**: (Whistler).

Digitaria radicosa (Presl) Miq.

Small erect grass with small narrowly lanceolate leaves, a panicle of 2 or 3 digitate branches, and paired, awnless, lanceolate spikelet. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Not found during the present survey.

Digitaria setigera Roth ex Roemer & Schultes

Medium-sized grass with palmately arranged spike branches spreading little at maturity and paired, unequally stalked, ovate spikelets. Occasional in sunny places. A Polynesian introduction or perhaps native. **KAO**: Buelow. Whistler 10684. **TOFUA**: Whistler 10547, 10670.

Eleusine indica (L.) Gaertn. takataka a le ala

Tufted, medium-sized grass with several panicle branches atop the rachis and one lower, and closely packed, awnless spikelets with the seed dropping free from them. Common as a weed of disturbed places. A Polynesian introduction. **KAO**: (Whistler). **TOFUA**: Scarth-Johnson.

Imperata cylindrica (L.) P. Beauv.

Medium-sized, rhizomatous grass with erect culms, a dense, cylindrical, silky panicle, and paired spikelets surrounded by silky hairs. Locally common in sunny places, especially in volcanic areas. Native, possibly a recent natural arrival. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta, Scarth-Johnson, Buelow. Often called *Imperata conferta* (Presl) Ohwi.

Lepturus repens (Forst. f.) R. Br.

Creeping grass rooting at the nodes, with spikelets embedded in a narrow spike rachis which splits into one-seeded sections at maturity. Common on littoral rocks and sand. Native. **TOFUA**: (Whistler).

Melinus repens (Willd.) G. Zizka salapona

Tall erect grass with an open, loose, rosy-purple panicle bearing numerous spikelets covered with long silky hairs. Locally common in disturbed places. A modern introduction. **TOFUA**: Whistler 10565. Often called *Rhynchelytrum repens* (Willd.) C.E. Hubb.

Miscanthus floridulus (Labill.) Warb. ex K. Sch. & Lauterb. kaho

Large, tufted reed with sharp-edged leaves, a large terminal panicle, and paired spikelets with a tuft of silky hairs at the base. Common in open areas and on cliffs. Native. The stems are used for rafter sticks and other parts of thatch houses. **KAO**: (Whistler). **TOFUA**: (Whistler).

Oplismenus compositus (L.) Beauv. musie vai?

Medium-sized grass with stems rooting at the lower nodes, a panicle of several raceme branches, and many awned spikelets. Common in forest clearings and disturbed places. Probably a Polynesian introduction. **KAO**: Yuncker, Buelow. Whistler 10710. **TOFUA**: Hotta, Buelow. Whistler 10533.

Panicum maximum Jacq. saafa

Large erect grass with large, light green leaves, a large terminal panicle with slender branches, and small ovate, awnless spikelets. Uncommon as a weed of disturbed places. A modern introduction. **TOFUA**: (Whistler).

Paspalum conjugatum Berg. vailima

Medium-sized grass with long stolons rooting at the nodes, a pair of narrow spikes atop the long stalk, and sessile, pubescent, ovate spikelets arranged in two rows along the rachis. Occasional as a weed of moist disturbed places. A modern introduction. **TOFUA**: Buelow. Whistler 10582.

Paspalum scrobiculatum L.

Erect, medium-sized grass with a panicle bearing several flattened, spreading branches bearing densely packed, flattened, oval spikelets. Occasional in fernlands and wetlands. Native. **KAO**: Yuncker. **TOFUA**: (Whistler). Often called *Paspalum orbiculare* Forst. f.

Schizachyrium fragilis (R. Br.) A. Camus

Small grass with thin, reddish, tufted stems, linear leaves, a terminal raceme, and awned spikelets with a dense fringe of silky hairs. Locally common on fernlands on the upper slopes of Tofua. A modern introduction? (known in the area only from Micronesia). **TOFUA**: Buelow. Whistler 10545.

Setaria pumila (Poir.) Roemer & Schultes

Medium-sized, weak-stemmed grass with a narrow, cylindrical panicle bearing crowded ovate spikelets surrounded by yellowish bristles arising from the base. Common as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Whistler 10678. Often called *Setaria glauca* (L.) Beauv.

Sorghum sudanense (Piper) Stapf kola

Large, coarse tufted grass with large leaves often spotted with brown, a terminal panicles of narrow branches, and unequal, awned, ovate spikelets arranged in 3s on the rachis. Common as a weed of disturbed places. A modern introduction. **KAO**: Buelow. Whistler 10678.

Sporobolus diander (Retz.) P. Beauv.

Small, clump-forming grass with linear leaves, a narrow panicle with short, ascending branches, and a small awnless spikelet containing a single seed that falls free from it. Common as a weed of disturbed places. A modern introduction. **TOFUA**: Buelow. Whistler 10560, 10617.

Stenotaphrum micranthum (Desv.) C.E. Hubb.

Creeping grass with linear-lanceolate leaves, terminal spikes, and spikelets embedded in the non-splitting rachis. Common on sandy beaches. Native. **KAO**: Buelow. Whistler 10732.

Thuarea involuta (Forst.) Roemer & Schultes kefukefu

Prostrate, creeping grass with softly hairy, lanceolate leaves, and spikelets on a narrow spike and enclosed at maturity within a capsule formed by a terminal spathe. Occasional in sunny littoral areas. Native. **KAO**: (Whistler).

TACCACEAE

Taccaleontopetaloides (L.)Kuntze mahoa'a

Tall, stemless herb with irregularly palmately lobed leaves, a leafless flowering stalk, and a inflorescence bearing greenish flowers and filamentous bracts. Occasional in littoral and coastal forest. A Polynesian introduction or indigenous. The tubers were formerly used as a famine food and for making paste employed in making tapa. **KAO**: Whistler 10726. **TOFUA**: Scarth- Johnson.

ZINGIBERACEAE

Zingiber zerumbet (L.) J.E. Sm. angoango

Tall, erect, rhizome-forming herb with alternate leaves and a leafless stalk bearing a terminal spike of white flowers borne between overlapping bracts. Occasional in forests and disturbed areas. A Polynesian introduction. The rhizome (foha) is used in Tongan medicines for treating mouth infections and enteritis. **TOFUA**: Scarth-Johnson.

GYMNOSPERMS

CYCADACEAE

Cycas rumphii Miq. longolongo

Cycad with pinnate fronds arising from the top of a trunk, male flowers in a large cone, and large, ovoid "fruits" arising on bracts between the leaves. Uncommon in forests and fernlands. Native. **TOFUA**: Scarth-Johnson.

FERNS

ADIANTIACEAE

Adiantum diaphanum Bl.

Small terrestrial fern with a shiny black stipe, lamina pinnate or with a pair of branches at the base, and round sori borne on the sinuses of the margin. Rare in shady places. Native. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Adiantum hispidulum Sw.

Small terrestrial fern with dark, shiny, hairy stipes, a pinnate lamina, flabellate pinnae, and sori on the dentate margins of the pinnae. Rare on moist rocks. Native. **KAO**: Buelow. **TOFUA**: Hotta. Not found during the present survey.

ANGIOPTERIDACEAE

Angiopteris evecta (Forst. f.) Hoffmann

Very large terrestrial fern with a globose base, long, thick stipes, a bipinnate lamina, mostly alternate pinnae, narrowly lanceolate, attenuate pinnules with subentire margins, and sori free from each other. Common in moist forest. Native. **TOFUA**: Hotta. Whistler 10626.

ASPIDIACEAE

Arachniodes aristata (Forst. f.) Tinsdale

Medium-sized terrestrial fern with a deltoid, tripinnate or more lamina, segments with aristate margins, and indusiate sori. Common in forests. Native. **KAO**: (Whistler). **TOFUA**: Hotta. Whistler 10597.

Tectaria dissecta (Forst. f.) Lellinger

Medium-sized terrestrial fern with tufted rhizomes, an ovate, predominately bipinnatifid lamina, and terminal sori with or without a kidney-shaped indusium. Uncommon in forests. Native. **KAO**: Buelow. Whistler 10697. **TOFUA**: Buelow. Hotta.

ASPLENIACEAE

Asplenium australasicum Hook. hakato

Large epiphytic or sometimes terrestrial, "nest-forming" fern with simple fronds, a large lamina, the midrib sharply keeled on lower surface, and sori arranged along veins from the midrib to the margin. Occasional in forests. Native. **KAO**: Yuncker. Whistler 10699. **TOFUA**: Hotta. Whistler 10561.

Asplenium obtusatum Forst. f.

Medium-sized terrestrial fern with scaly stipes, a broadly ovate, pinnate lamina, pinnae blunt at the apex, and linear sori reaching nearly to the margin. Rare in forests. Native. **TOFUA**: Hotta. Not found during the present survey.

Asplenium polyodon Forst. f.

Medium-sized epiphytic or sometimes terrestrial fern with a pinnate, non-proliferous lamina, up to 15 pairs of unequally sided, acuminate-tipped pinnae, and long sori covering most of the length of the vein. Occasional in lowland and coastal forest. Native. **TOFUA**: Scarth-Johnson, Hotta. Whistler 10647.

Loxoscaphe gibberosum (Forst. f.). Moore

Medium-sized terrestrial fern with clustered stipes, a broadly ovate, 4--5-divided lamina, linear ultimate segments, and a lateral, cuplike sorus on the segments. Locally common in moist places. Native. **KAO**: Yuncker. Whistler 10711. **TOFUA**: Whistler 10601.

ATHYRIACEAE

Lunathyrium japonicum (Thunb.) Kurata

Medium-sized terrestrial fern with stipes covered with pale narrow scales, a deeply bipinnatifid lamina, narrow, deeply lobed, hairy pinnae, and short indusiate sori. Rare in wet places. Native. **KAO**: Yuncker; Buelow. Not found during the present survey.

BLECHNACEAE

Blechnum vulcanicum (Bl.) Kuhn

Medium-sized terrestrial fern with dimorphic lamina, sterile ones pinnate at base, pinnatifid at the top, the 1--3 basal pinnae pairs deflexed, and sori on the lower lamina surface of the fertile fronds. Common and sometimes dominant in the upper elevation volcanic areas. Native. **KAO**: Yuncker. Whistler 10720. **TOFUA**: Whistler 10605.

CYATHEACEAE

Cyathea decurrens (Hook.) Copel.

Small, low tree fern basal scales on the stipes, a quadripinnate to quadripinnatifid lamina, upper rachis with a row of hairs, and small sori protected by an inconspicuous indusium. Common at upper elevations on Kao. Native. **KAO**: Buelow. Whistler 10715.

Cyathea lunulata (Forst. f.) Copel. ponga

Large tree fern with erect to ascending fronds, pale brown scales on the stipe base, a warty rachis, a tripinnate lamina, and small sori protected by an inconspicuous indusium. Common in lowland to montane forest. Native. The trunks are used as a substrate for orchids, and were formerly eaten cooked in time of famine. **KAO**: Yuncker, Buelow. **TOFUA**: Hotta.

DAVALLIACEAE

Davallia solida (Forst. f.) Sw. kulutuma

Medium-sized epiphytic fern with a creeping rhizome, a deltoid, tripinnate to tripinnatifid lamina, and sori on a tubular indusium truncate on the outer margin. Common in forests. Native. The fronds are sometimes used for decoration. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10604.

Humata heterophylla (J.E. Sm.) Desv.

Small epiphytic fern with long creeping rhizomes, dimorphic fronds, a simple, sterile lamina lanceolate with entire margins, pinnatifid fertile fronds lobed over half way to the margins, and indusiate sori borne one to each tooth of the lobes. Uncommon in forests. Native. **TOFUA**: Buelow. Whistler 10610.

Humata polypodioides Brack.

Small epiphytic fern with a long-creeping rhizome, deltoid, a deeply pinnatifid, homogeneous lamina, fertile segments slightly narrower than the sterile ones, and indusiate sori borne one to each teeth of the lobes. Uncommon in forests. Native. **KAO**: Buelow. Whistler 10702.
TOFUA: Buelow.

GLEICHENIACEAE

Dicranopteris linearis (Burm.) Underw. kahiva'e

Large terrestrial fern with stipes forked 1--3 times, a bipinnatifid lamina lobed to near the costa, linear segments, and about a dozen sori on the undersurface of the segments. Locally abundant on fernlands. Native. **KAO**: Yuncker, Hotta. **TOFUA**: Scarth-Johnson.

Gleichenia sp. indet.

Medium-sized terrestrial fern with stipes dichotomously branched 4--5 times with deltoid stipular leaflets at their bases, linear segments, and several sori on the undersurface of the segments. Uncommon in montane fernlands on Kao. Native. **KAO**: Whistler 10722. It does not appear to match other species of **Gleichenia** in the area.

GRAMMITIDACEAE

Ctenopteris blechnoides (Greville) Wagner & Grether

Small epiphytic fern with clustered stipes, a pinnate, subsessile lamina attentuate at both ends, linear segments, and oblong sori on the upper segments. Uncommon in forests. Native. **KAO**: Whistler 10704. **TOFUA**: Buelow. Whistler 10637.

HEMIONITIDACEAE

Pityrogramma brackenridgei (Carruthers) Maxon

Small terrestrial fern with an erect rhizome, a bipinnatifid to nearly bipinnate lamina, and silvery sori covering the entire lower surface of the pinnae. Rare in sunny volcanic areas. Native. **TOFUA**: Hotta, Buelow. Whistler 10629.

HYMENOPHYLLACEAE

Hymenophyllum polyanthos Sw.

Small epiphytic fern with a winged stipe, a bipinnate to tripinnate, membranous lamina, and terminal sori on short segments and protected by a rounded indusium. Locally common in wet forests. Native. **TOFUA**: Buelow. Whistler 10613.

Trichomanes apiifolium Presl

Erect, medium-sized terrestrial fern with tufted stipes, long reddish hairs on the stipe and rachis, a tripinnate or more divided lamina, pinnae in one plane, ultimate segments linear, and a terminal sorus on a receptacle. Native. **KAO**: Whistler 10712. **TOFUA**: Hotta? (an unidentified **Trichomanes** species collected by Hotta was not seen).

Trichomanes asae-grayi v.d. Bosch

Small, erect terrestrial fern with long hairs on the stipe and rachis, a tripinnate or more divided, cylindrical lamina, and a terminal sorus on a receptacle. Native. **KAO**: Buelow. Not found during the present survey.

Trichomanes boryanum Kuntze

Small terrestrial fern with tufted stipes, a pinnate lamina, narrowly oblong pinnae in one plane, and the sori on receptacles borne on the upper margins of the segments. Uncommon in shady, moist forests. Native. **TOFUA**: Hotta, Buelow. Whistler 10627.

Trichomanes humile Forst. f.

Tiny epiphytic fern with a winged rachis, a bipinnatifid lamina, margins of pinnae with 2 rows of elongate cells, and sori on a receptacle with the tube narrowly winged. Locally common in forests. Native. **KAO**: Whistler 10728. **TOFUA**: Hotta; Whistler 10625.

Trichomanes saxifragoides Presl

Tiny epiphytic fern with a creeping rhizome, a flabellate, almost round lamina, and sori immersed in segments and protected by a tubular, winged indusium. Locally common in moist forests. Native. **TOFUA**: Hotta, Buelow. Whistler 10596.

Trichomanes taitense Nadeau

Small epiphytic fern with a widely creeping rhizome, no stipe, a peltate, round lamina, and 1--3 sori on the lamina and protruding beyond the margin. Uncommon in forests. Native. **KAO**: Buelow.

HYPOLEPIDACEAE

Histiopteris incisa (Thunb.) J. Sm.

Large terrestrial fern with dark shiny stipes, a tripinnatifid lamina, opposite primary pinnae, and sori continuous on the margins of the segments except at the tips. Occasional to common in sunny places at higher elevations. Native. **KAO**: Yuncker. Whistler 10707. **TOFUA**: Whistler 10554.

Hypolepis tenuifolia (Forst. f.) Bernh.

Large terrestrial fern with paired dark vertical bands on the stipe, a 4--5-pinnate lamina, and sori on the ultimate segments and covered with a flap of the segment margin. Uncommon in sunny places. Native. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Pteridium esculentum (Forst. f.) Cockayne

Large coarse fern with spreading stems, tripinnate to quadripinnatifid laminas, costules and veins hairy on lower surface, and sori continuous around the segment margins. Common in low-elevations fernlands. Native. **KAO**: (Whistler). **TOFUA**: Hotta, Buelow.

LINDSAEACEAE

Lindsaea ensifolia Sw.

Medium-sized terrestrial fern with a pinnate to bipinnate lamina, 8--15 pinnae pairs, pinnae lanceolate, and sori continuous on the lobe margins. Occasional in open, often degraded areas. Native. **KAO**: Yuncker. **TOFUA**: Hotta. Whistler 10667.

Lindsaea harveyi Carr. ex Seem.

Medium-sized terrestrial fern with a short-creeping rhizome, bipinnate or sometimes subtripinnate lamina, 1--5 pinnae per side and a similar terminal one, and short sori one to a lobe. Rare in forests. Native. **TOFUA**: Buelow. Whistler 10662.

Sphenomeris chinensis (L.) Maxon

Medium-sized terrestrial fern with tufted stipes, a tripinnate to quadripinnatifid, ovate to lanceolate lamina, cuneate ultimate segments, and terminal sori close to apex of the segment and opening towards the margin. Occasional in sunny and volcanic places. Native. **KAO**: Yuncker. Whistler 10706. **TOFUA**: Hotta. Whistler 10630.

LOMARIOPSIDACEAE

Elaphoglossum feejeense Brack.

Medium-sized epiphytic fern with a short-creeping rhizome, an oblanceolate lamina densely dotted beneath with small scales, and sori covering the underside the the fertile fronds. Common in forests. Native. **KAO**: (Whistler). **TOFUA**: Hotta. Whistler 10611.

MARATTIACEAE

Marattia smithii Mett.

Large terrestrial fern with a large, globose base, long thick stipes, a bipinnate lamina, mostly opposite pinnae, lanceolate, attenuate pinnules with serrate margins, and sori in a cluster enclosed in a purselike structure. Common in moist forest. Native. **KAO**: Whistler 10705. **TOFUA**: Whistler 10663. A new record for Tonga.

NEPHROLEPIDACEAE

Nephrolepis hirsutula (Forst. f.) Presl hulufe

Large terrestrial fern with red-brown scaly stipes and rachis, a pinnate lamina, narrowly lanceolate pinnae with an auricle on the upper margin, and sori close to the margin. Common to abundant in sunny areas and forest clearings. Native. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson, Buelow.

OPHIOGLOSSACEAE

Ophioglossum petiolatum Hooker

Tiny terrestrial fern with an erect rhizome, a frond consisting of an ovate lamina and a fertile spike, and sori arranged on the unbranched spike. Rare in sunny volcanic areas. Native. **TOFUA**: Buelow. Whistler 10632. A new record for Tonga, first collected by Buelow in 1982.

Ophioglossum pendulum L.

Small to medium-sized, epiphytic fern with simple, linear, pendulous fronds and sori on a hanging spike attached near the middle of the lamina. Occasional in forests. Native. **TOFUA**: Hotta. Whistler 10636.

POLYPODIACEAE

Belvisia mucronata (Fee) Copel.

Small epiphytic fern with a short-creeping rhizome, a simple, lanceolate lamina, and sori covering on the undersurface of the attenuate, narrow tip of the fertile fronds. Common in forests. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Buelow. Whistler 10608.

Phymatosorus grossus (Langsd. & Fisch.) Brownlie laufale

Medium-sized terrestrial or epiphytic fern with a scaly, creeping rhizome, pinnatifid lamina, 1--10 pairs of lobes, and sori in 1 or 2 rows on either side of the midrib of the lobes. Common in forests. Native. An extract of the rhizome is commonly used for treating inflammation. **KAO**: Yuncker. **TOFUA**: Scarth-Johnson. Often mistakenly identified as *Phymatosorus scolopendria* (Burm. f.) Pichi Serm.

PTERIDACEAE

Acrostichum aureum L. hakato

Tall, clump forming terrestrial fern with a leathery, pinnately divided lamina with the lower surface of the fertile fronds covered with a velvety layer of sori. Occasional on coastal rocks. Native. **KAO**: (Whistler). **TOFUA**: Scarth-Johnson.

Pteris comans Forst. f.

Large terrestrial fern with erect, bipinnate to tripinnatifid fronds, basal pinna with one lobe longer than the others, and the sori continuous along the pinnae margins except the tip. Common to dominant in shady forest. Native. **TOFUA**: Whistler 10638.

Pteris ensiformis Burm. f.

Medium-sized terrestrial fern with a creeping rhizome, dimorphic fronds, a pinnate lamina, long, narrow, obliquely ascending pinnae of fertile fronds, and sori continuous along most of the lobe margin. Uncommon in coastal and lowland forest. Native. **KAO**: Buelow. **TOFUA**: Whistler 10673.

Pteris pacifica Hier.

Medium-sized terrestrial fern with a purple rachis and stipe, deeply pinnatifid lamina, pinnae lobed to near the costa, soft spines on the costule junction, and sori nearly continuous on the pinna margin. Rare in forests. Native. **TOFUA**: Hotta, Buelow. Not found during the present survey.

Pteris vittata L.

Medium-sized terrestrial fern with scaly stipes, a pinnate lamina, and sori forming a marginal row to near the tip of the pinnules. Uncommon in sunny places. Native. **TOFUA**: Scarth- Johnson. Whistler 10658.

SCHIZAEACEAE

Schizaea dichotoma (L.) J.E. Sm. masalu

Small terrestrial fern with a dichotomously branched, a flabellate lamina, the ultimate segments winged, and sori terminal on the fertile lobes. Occasional in forests. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Scarth-Johnson. Whistler 10572.

Schizaea melanesica Selling

Small to medium-sized terrestrial fern with tufted fronds, erect, linear, simple laminas, and 3-linear, digitate linear segments at the tips of the fertile fronds. Occasional in forests. Native. **KAO**: Whistler 10730. **TOFUA**: Hotta. Whistler 10620.

THELYPTERIDACEAE

Christella harveyi (Mett.) Holttum

Large terrestrial fern with a pinnate lamina, pinnae lobed to near the costa, the lowest 3--5 pairs much reduced, veins free, and sori submarginal on the segments. Common in forests. Native. **KAO**: (Whistler). **TOFUA**: Hotta; Scarth-Johnson, Buelow. Whistler 10567.

Macrothelypteris polypodioides (Hooker) Holttum

Large terrestrial fern with scale and septate hairs on the rachis, a bipinnate to tripinnatifid lamina, and small indusiate sori. Uncommon in sunny places. Native. **KAO**: Buelow. **TOFUA**: Hotta, Buelow. Whistler 10580, 10622.

Macrothelypteris torresiana (Gaud.) Ching

Large terrestrial fern with a tripinnatifid lamina, rachis and lower surfaces of pinnules with slender septate hairs but no pinnate scales, and small indusiate sori. Occasional in sunny places. Native. **TOFUA**: Hotta. Not found during the present survey.

Pneumatopteris macroptera (Copeland) Holttum

Large terrestrial fern with fronds up to 2 m long, a straw- colored rachis, a pinnate lamina, pinnae divided about halfway to the costa, lobes shallowly crenate, and numerous round sori. Uncommon in forests. Native, endemic to Tonga. **KAO**: Buelow. **TOFUA**: Buelow. Not found during the present survey.

Sphaerostephanos invisus (Forst. f.) Holttum

Large terrestrial fern with pinnate scales on the rachis and stipe, a bipinnatifid lamina, lower 2 or more pinnae reduced, no yellow glands present, and sori with a hairy indusium. Occasional in fernlands and sunny disturbed places. Native. **TOFUA**: Buelow. Whistler 10672.

Sphaerostephanos unitus (L.) Holttum

Large terrestrial fern with a bipinnatifid lamina, pinnae cut about 1/3 of the way to the costa, lower 6 or more pairs reduced, lower pinna surface pubescent and yellow-glandular, and sori with a short-hairy indusium. Locally common in sunny disturbed places. Native. **KAO**: Yuncker. Whistler 10718. **TOFUA**: Whistler 10624, 10671.

VITTARIACEAE

Antrophyum alatum Brack.

Small epiphytic fern with tufted stipes, a simple, entire, obovate lamina, and linear sori covering the veins of the lower lamina surface. Uncommon in forests. Native. **KAO**: Buelow. Not found during the present survey.

Antrophyum plantagineum (Cav.) Kaulf.

Small epiphytic fern with tufted stipes, a simple, entire, linear-oblanceolate to falcate lamina, and linear sori covering the veins of the slower surface. Uncommon in forests. Native. **TOFUA**: Buelow. Not found during the present survey.

FERN ALLIES

LYCOPODIACEAE

Lycopodium cernuum L. hiku 'i kuli

Medium-sized terrestrial fern ally with linear sterile leaves less than 1 mm wide and sporophylls (fertile leaves) borne in distinct, short, unforked spikes. Locally common in fernlands. Native. **KAO**: Yuncker. Whistler 10723. **TOFUA**: Hotta, Scarth- Johnson.

Lycopodium phlegmaria L.

Small epiphytic fern ally with spreading, ovate, sterile leaves and strobili of tiny sporophylls borne terminal forked spikes. Uncommon in forests. Native. **TOFUA**: Buelow. Whistler 10640.

Lycopodium squarrosum Forst. f.

Medium-sized terrestrial fern ally with branched, bottlebrush- like stems, sterile leaves and sporophylls similar, linear, with entire margins. Uncommon in fernlands. Indigenous, ranging from tropical Asia to Polynesia. **KAO**: Buelow. **TOFUA**: Whistler 10643.

Lycopodium clavatum L.

Small terrestrial fern ally with a long-creeping rhizome, small linear, appressed sterile leaves, and sporophylls in 2--6 distinct spikes on an erect stalk. Locally common in fernlands at high elevations. Native. **KAO**: Buelow. Whistler 10708. Perhaps identical with **Lycopodium venustulum** Gaud. reported from Hawaii and Samoa.

PSILOTAECAE

Psilotum nudum (L.) Beauv.

Small terrestrial or epiphytic fern-ally with scalelike leaves, erect stems triangular in cross-section, and sori on short terminal and lateral branches. Occasional in rocky places or forests. Native. **KAO**: Yuncker. **TOFUA**: Hotta, Buelow. Whistler 10609.

SELAGINAELLACEAE

Selaginella laxa Spring

Tiny prostrate terrestrial fern ally with creeping stems, tiny, dimorphic leaves, and sori borne on sporophylls arranged in terminal strobili. Uncommon in moist sunny places. Native. **TOFUA**: Hotta, Buelow. Whistler 10619.

Selaginella yunckeri Alston

Small terrestrial herb with erect, scaly stems, small scalelike leaves, and sori borne on sporophylls arranged in terminal strobili. Common in some wet sunny places, like at the summit of Kao. Native, endemic to Tonga. **KAO**: Yuncker, Buelow. Whistler 10714. **TOFUA**: Hotta, Buelow.

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TABLE 3. CHECKLIST OF CULTIVATED PLANTS NOTED ON KAO AND TOFUA.

Scientific Name	FAMILY Tongan Name	English Name
	DICOTS	
	ANACARDIACEAE	
Anacardium indicum	telie papalagi	cashew

Mangifera indica	mango	mango
Spondias dulcis (n.s.)	vi	Otahiti apple
ANNONACEAE		
Cananga odorata	mohokoi	ilangilang
APOCYNACEAE		
Plumeria rubra	kalosipani	frangipani
ARALIACEAE		
Polyscias scutellaria	tanetane	panax
BOMBACACEAE		
Ceiba pentandra	vavae	kapok
BRASSICACEAE		
Brassica oleracea (n.s.)	kapisi	cabbage
BURSERACEAE		
Garuga floribunda (n.s.)	manaui	-----
CLUSIACEAE		
Garcinia sessilis (n.s.)	heilala	-----
CONVOLVULACEAE		
Ipomoea batatas (n.s.)	kumala	sweet potato
CUCURBITACEAE		
Citrullus lanulatus (n.s.)	meleni	watermelon
EUPHORBIACEAE		
Aleurites moluccana	hiapo	
Codiaeum variegatum	tanetane vao?	croton
Jatropha curcas	fiki	physic nut
Manihot esculenta	manioke	cassava
FABACEAE		
Derris malaccensis (n.s.)	kava fisi	derris
Inocarpus fagifer	ifi	Polynesian chestnut
MALVACEAE		
Hibiscus manihot	pele	tree spinach
Hibiscus rosa-sinensis	kaute	red hibiscus
Hibiscus schizopetalous	kaute	fringed hibiscus
MORACEAE		
Artocarpus altilis	mei	breadfruit
MYRTACEAE		
Syzygium corynocarpum	hehea	-----
Syzygium malaccense (n.s.)	fekika kai	Malay apple
Syzygium neurocalyx (n.s.)	koli	-----
PASSIFLORACEAE		
Passiflora edulis	vaini	passionfruit
PIPERACEAE		
Piper methysticum	kava	kava

FAMILY Scientific Name	Tongan Name	English Name

	RUBIACEAE		
Coffea arabica (n.s.)		kofe	coffee
	RUTACEAE		
Euodia hortensis		uhi	island musk
Citrus medica		lemani petepete	citron
Citrus sp.	kola		-----
	SOLANACEAE		
Capsicum frutescens		polo fifisi	chili pepper

MONOCOTS

	AMARYLLIDACEAE		
Crinum xanthophyllum (n.s.)		samoa	crinum lily
Hymenocallis littoralis		lile	spider lily
	ARACEAE		
Alocasia macrorrhiza (n.s.)		kape	giant taro
Colocasia esculenta (n.s.)		talo tonga	taro
Xanthosoma nigrum		talo futuna	American taro
	ARECACEAE		
Pritchardia pacifica (n.s.)		piu	Fiji fan palm
	BROMELIACEAE		
Ananas comosa		fala	pineapple
	DIOSCORACEAE		
Dioscorea alata		ufi	yam
Dioscorea esculenta (n.s.)		ufilei	yam
Dioscorea nummularia? (n.s.)		sivoli	spiny yam
	MUSACEAE		
Musa x paradisiaca		fusi	banana
	ORCHIDACEAE		
Vanilla planifolia		vanila	vanila
	POACEAE		
Cymbopogon citratus		moegalo	lemon grass
Saccharum officinarum		au, to	sugarcane
Zea mays (n.s.)		koane	corn

Plants on this list were either seen or their presence was verified by informants. Those not seen are marked with (n.s.)

TABLE 4. VEGETATION TYPES PRESENT ON KAO AND TOFUA (MODIFIED AFTER WHISTLER 1992B).

DISTURBED VEGETATION
1. Managed Land
2. Secondary Scrub
3. Secondary Forest

FERNLAND VEGETATION
4. Toafa Fernland
   A. *Pteridium* Toafa
   B. *Dicranopteris* Toafa
5. Montane Fernland

LITTORAL VEGETATION
6. Littoral Strand
7. Littoral Forest

VOLCANIC VEGETATION 8. Volcanic Scrub
9. Toa (*Casuarina*) Woodland

RAINFOREST VEGETATION
10. Lowland Forest
   A. Tamanu Forest
   B. Makai Forest

TABLE 5. SURVEY PLOT DATA FROM KAO AND TOFUA

PLOT 1. Secondary forest, north coast of Tofua (9 July 1977). 40 m elevation.

Species Name	Tongan Name	No. of Trees	No. of Trees over 15 cm dbh	Basal Area (cm2)	Relative Dominance
1. Casuarina equisetifolia	toa	2	2	12,156	27%
2. Ficus obliqua	ovava	2	2	7,323	17%
3. Rhus taitensis	tavahi	34	11	6,572	15%
4. Cocos nucifera	niu	5	4	2,334	5%
5. Elattostachys falcata	ngatata	11	6	2,091	5%
6. Syzygium crosbyi	fekika vao	5	1	1,745	4%
7. Heritiera ornithocephala	ifiifi	4	2	1,710	4%

8. Alphitonia zizyphoides 3%	toi	3	2	1,519
9. Elaeocarpus tonganus 3%	ma'ama'alava	9	2	1,381
10. Morinda citrifolia 2%	nonu	9	2	1,050
11. Diospyros elliptica 2%	kanume	5	2	1,050
12. Planchonella grayana 1%	kalaka	2	2	660
13. Guettarda speciosa 1%	puopua	3	1	631
14. Ficus scabra 1%	masi'ata	9	0	565
15. Hibiscus tiliaceus 1%	fau	4	1	480
16. Calophyllum neo-ebud. 1%	tamanu	5	0	469
17. Vavaea amicorum 1%	ahivao	6	0	456
18. Cyclophyllum barbatum 1%	olamaka	3	1	402
19. Pandanus tectorius 1%	fafa	2	1	331
20. Grewia crenata 1%	fo'ui	5	0	313
21. Macaranga harveyana 1%	loupata	1	1	271
22. Geniostoma rupestre 1%	te'epilo a maui	4	0	258
23. Diospyros samoensis +	tutuna	1	0	217
24. Psychotria insularum +	olavai	5	0	162
25. Celtis harperi? +	kaukau'ulie?	2	0	66
Area: 1000 m2		141	43	43,212

Other Trees: Glochidion ramiflorum, Pittosporum arborescens, Syzygium clusiifolium?, Terminalia littoralis. **Ferns (Terrestrial):** Asplenium australasicum, Christella harveyi? (*), Davallia solida, Nephrolepis hirsutula, Schizaea dichotoma. **Ferns (Epiphytic):** None recorded. **Vines:** Abrus precatorius, Hoya australis, Jasminum simplicifolium, Morinda myrtifolia, Rourea minor. **Orchids:** None recorded. **Others**: Alyxia stellata (**), Cordyline fruticosa, Macropiper puberulum.

PLOT 2. Afa secondary forest, inside north crater rim of Tofua (14 July 1977). 370 m elevation.

Species Name	Tongan Name	No. of Trees	No. of Trees over 15 cm dbh	Basal Area (cm2)	Relative Dominance
1. Neonauclea forsteri	afa	9	7	19,381	43%
2. Calophyllum neo-ebud.	tamanu	11	8	11,499	25%
3. Cyathea lunulata	ponga	9	7	4,513	10%
4. Elattostachys falcata	ngatata	8	4	1,696	4%
5. Rhus taitensis	tavahi	2	2	1,508	3%
6. Canarium vitiense	ma'ali	2	1	893	2%
7. Elaeocarpus tonganus	ma'ama'alava	7	1	820	2%
8. Diospyros samoensis	tutuna	3	2	770	2%
9. Ficus scabra	masi'ata	9	2	731	2%
10. Garcinia myrtifolia	feto'umaka	4	1	634	1%
11. Fagraea berteroana	pua	4	2	578	1%
12. Geniostoma rupestre	te'epilo a maui	3	1	572	1%
13. Heritiera ornithocephala	ifiifi	1	1	572	1%
14. Psychotria insularum	olavai	9	0	480	1%
15. Melicope retusa	-----	2	1	355	1%
16. Vavaea amicorum	ahivao	3	0	254	1%
17. Myristica hypargyraea	kotone	1	0	79	+
18. Cordyline fruticosa si		2	0	56	+
Area: 1000 m2		89	40	45,391	

Other Trees: Alphitonia zizyphoides (s), Ficus obliqua. **Ferns (Terrestrial):** Angiopteris evecta (*), Christella harveyi, Lindsaea harveyi, Loxoscaphe gibbosa (*), Marattia smithii (*),

Nephrolepis hirsutula, Pteris comans (**), Schizaea dichotoma. **Ferns (Epiphytic):** Belvisia mucronata, Davllia solida, Elaphoglossum feejeense, Humata heterophylla (*), Loxoscaphe gibberosum, Ophioglossum pendulum, Trichomanes humile, Trichomanes saxafragoides (*). **Vines:** Faradaya amicorum? (*), Hoya australis, Jasminum simplicifolium, Rourea minor. **Orchids:** Bulbophyllum cf. membranaceum (e), Calanthe hololeuca, Dendrobium calcaratum (e), Erythrodes oxyglossa, Erythrodes parvula, Liparis layardii, Phaius cf. flavus, Phreatia micrantha (e). **Others:** Alyxia stellata, Macropiper puberulum.

PLOT 3. Tamanu lowland forest, south slope of Kao (18 July 1977). 250 m elevation.

Species Name	Tongan Name	No. of Trees	No. of Trees over 15 cm dbh	Basal Area (cm2)	Relative Dominance
1. Calophyllum neo-ebud.	tamanu	82	32	18,305	50%
2. Elattostachys falcata	ngatata	17	12	5,899	16%
3. Syzygium brackenridgei	fekika vao	27	9	3,799	10%
4. Alphitonia zizyphoides	toi	3	2	2,255	6%
5. Cyathea lunulata	ponga	6	6	1,827	5%
6. Garcina myrtifolia	feto'umaka	8	1	912	3%
7. Elaeocarpus tonganus	ma'ama'alava	3	1	771	2%
8. Canarium vitiense	makai	6	1	674	2%
9. Geniostoma rupestre	te'epilo a maui	2	1	586	2%
10. Tarenna sambucina	manonu	1	0	283	1%
11. Heritiera ornithocephala	ifiifi	4	0	274	1%
12. Syzygium crosbyi	fekika vao	2	1	229	1%
13. Pittosporum arborescens	masikona	1	1	201	1%
14. Vavaea amicorum	ahivao	3	0	122	+

15. Diospyros samoensis +	tutuna	2	0	92
16. Psychotria insularum +	olavai	1	0	64
17. Glochidion ramiflorum +	malolo	1	0	20
Area: 1000 m2		169	67	36,313

Other Trees: Diospyros elliptica (s), Ficus scabra, Ficus tinctoria, Myristica hypargyraea. **Ferns (Terrestrial):** Arachniodes aristata, Christella harveyi (*), Schizaea melanesica. **Ferns (Epiphytic):** Belvisia mucronata, Davallia solida, Loxoscaphe gibberosum, Trichomanes humile. **Vines:** Faradaya amicorum, Jasminum simplicifolium, Morinda myrtifolia, Rourea minor (*). **Orchids:** Dendrobium platygastrum (e), Malaxis brevidentata, Phreatia micrantha (e)(*). **Others**: Alyxia stellata (*), Macropiper puberulum.

PLOT 4. Tamanu lowland forest, east crater rim of Tofua (15 July 1977). 400 m elevation.

Species Name	Tongan Name	No. of Trees	No. of Trees over 15 cm dbh	Basal Area (cm2)	Relative Dominance
1. Calophyllum neo-ebud.	tamanu	14	13	20,130	39%
2. Syzygium brackenridgei	fekika vao	30	11	4,700	9%
3. Alphitonia zizyphoides	toi	9	9	4,444	9%
4. Fagraea berteroana	pua	10	6	3,141	6%
5. Neonauclea forsteri	afa	14	7	2,954	6%
6. Casuarina equisetifolia	toa	1	1	2,641	5%
7. Cyathea lunulata	ponga	6	5	2,495	5%
8. Elattostachys falcata	ngatata	14	5	2,423	5%
9. Canarium vitiense	makai	12	7	2,344	5%
10 Elaeocarpus tonganus	ma'ama'alava	9	1	1,084	2%

11. Rhus taitensis 2%	tavahi	3	2	1,079
12. Geniostoma rupestre 2%	te'epilo a maui	11	1	1,008
13. Ficus obliqua 2%	ovava	2	1	786
14. Glochidion ramiflorum 1%	malolo	5	1	740
15. Psychotria insularum 1%	olavai	8	0	342
16. Ficus scabra 1%	masi'ata	5	0	298
17. Myristica hypargyraea 1%	kotone	3	0	266
18. Diospyros samoensis +	tutuna	3	0	203
Area: 1000 m2		159	70	51,078

Other Trees: Ficus tinctoria, Heritiera ornithocephala, Melicope retusa, Polyscias multijuga, Vavaea amicorum. **Ferns (Terrestrial):** Angiopteris evecta, Arachniodes aristata (*), Christella harveyii (**), Loxoscaphe gibberosum, Marattia smithii (*), Nephrolepis hirsutula, Pteris comans (*), Schizaea dichotoma. **Ferns (Epiphytic):** Belvisia mucronta, Davallia solida, Elaphoglossum feejeense, Humata heterophylla (*), Hymenophyllum polyanthos, Loxoscaphe gibberosum, Lycopodium phyllanthum, Trichomanes saxifragoides. **Vines:** Faradaya amicorum, Gynochtodes epiphytica, Hoya australis, Jasminum simplicifolium, Morinda myrtifolia, Rourea minor.
Orchids: Bulbophyllum cf. membranaceum (e), Bulbophyllum pachyanthum (e), Calanthe hololeuca, Dendrobium calcaratum (**)(e), Erythrodes oxyglossa, Erythrodes parvula, Liparis layardii, Phreatia micranthum (e). **Others:** Alyxia stellata, Cordyline fruitcosa, Cyrtandra samoensis, Cyrtococcum oxyphyllum, Macropiper puberulum, Mussaenda raiateensis.

PLOT 5. Makai lowland forest, inside north crater rim of Tofua (15 July 1977). 290 m elevation.

Species Name	Tongan Name	No. of Trees	No. of Trees over 15 cm dbh	Basal Area (cm2)	Relative Dominance
1. Canarium vitiense	makai	7	6	15,343	41%
2. Calophyllum neo-ebud.	tamanu	13	5	6,065	16%

3. Alphitonia zizyphoides 12%	toi	2	2	4,647
4. Myristica hypargyraea 7%	kotone	5	3	2,759
5. Neonauclea forsteri 6%	afa	6	4	2,059
6. Elattostachys falcata 5%	ngatata	8	2	2,005
7. Cyathea lunulata 4%	ponga	8	4	1,448
8. Heritiera ornithocephala 4%	ifiifi	2	1	1,371
9. Fagraea berteroana 1%	pua	1	1	518
10. Garcinia myrtifolia 1%	feto'umaka	3	0	224
11. Psychotria insularum 1%	olavai	4	0	203
12. Ficus scabra +	masi'ata	2	0	174
13. Elaeocarpus tonganus +	ma'ama'alava	2	0	153
14. Geniostoma rupestre +	te'epilo a maui	2	0	114
15. Melicope retusa +	-----	3	0	104
Area: 1000 m2		68	28	37,187

Other Trees: Diospyros samoensis, Ficus obliqua, Ficus tinctoria. **Ferns (Terrestrial):** Arachniodes aristata, Christella harveyi (**), Davallia solida, Marattia smithii (*), Nephrolepis hirsutula, Pteris comans (*), Schizaea dichotoma, Trichomanes boryanum. **Ferns (Epiphytic):** Belvisia mucronata (*), Davallia solida, Elaphoglossum feejeense, Humata heterophylla, Loxoscaphe gibberosum, Trichomanes saxafragoides. **Vines:** Faradaya amicorum, Gynochtodes epiphytica, Hoya australis, Jasminum simplicifolium, Rourea minor (*). **Orchids:** Appendicula reflexa (e), Bulbophyllum cf. membranaceum (e), Calanthe hololeuca, Dendrobium calcaratum (e) (*), Erythryodes parviflora, Erythrodes oxyglossa. **Others:** Alyxia stellata, Cyrtandra samoensis.

PLOT 6. Makai lowland forest, inside east crater rim of Tofua (11 July 1977). 140 m elevation.

Species	Tongan	No. of	No. of Trees	Basal Relative

Name	Name	Trees	over 15 cm dbh	Area (cm2)
Dominance				
1. Canarium vitiense	makai	12	8	21,070
42%				
2. Myristica hypargyraea	kotone	14	10	9,832
19%				
3. Cyathea lunulata	ponga	7	6	6,070
12%				
4. Calophyllum neo-ebud.	tamanu	19	6	4,604
9%				
5. Neonauclea forsteri	afa	6	4	4,070
8%				
6. Elaeocarpus tonganus	ma'ama'alava	14	5	2,676
5%				
7. Elatostachys falcata	ngatata	1	1	1,734
3%				
8. Ficus scabra	masi'ata	5	0	502
1%				
9. Heritiera ornithocephala	ifiifi	2	0	88
+				
10. Psychotria insularum	olavai	1	0	50
+				
11. Syzygium cf. crosbyi	fekika vao	2	0	48
+				
Area: 1000 m2		83	40	50,744

Other Trees: Alphitonia zizyphoides, Diospyros elliptica (s), Diospyros samoensis (s), Ficus tinctoria, Garcinia myrtifolia, Glochidion ramiflorum (s), Morinda citrifolia, Mussaenda raiateensis, Rhus taitensis (s), Syzygium brackenridgei, Tarenna sambucina, Vavaea amicorum. **Ferns (Terrestrial):** Angiopteris evecta (*), Arachniodes aristata (*), Christella harveyi, Davallia solida, Pteris comans (*), Schizaea dichotoma, Trichomanes boryanum. **Ferns (Epiphytic):** Asplenium australasicum, Trichomanes humile, Trichomanes saxifragoides. **Vines:** Entada phaseoloides, Faradaya amicorum (**), Jasminum simplicifolium, Morinda myrtifolia, Rouria minor. **Orchids:** Phaius tankervilliae?: **Others:** Alyxia stellata, Cordyline fruticosa, Macropiper puberulum.

NOTE: A plant followed by an (s) indicates that only saplings of that species were found in the plot. A plant followed by an (e) is an epiphyte. Plants followed by a (*) were common in the plot, and those followed by a (**) were very common,.