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AN ECOLOGICAL RECONNAISSANCE OF TETIAROA ATOLL, SOCIETY ISLANDS

BY

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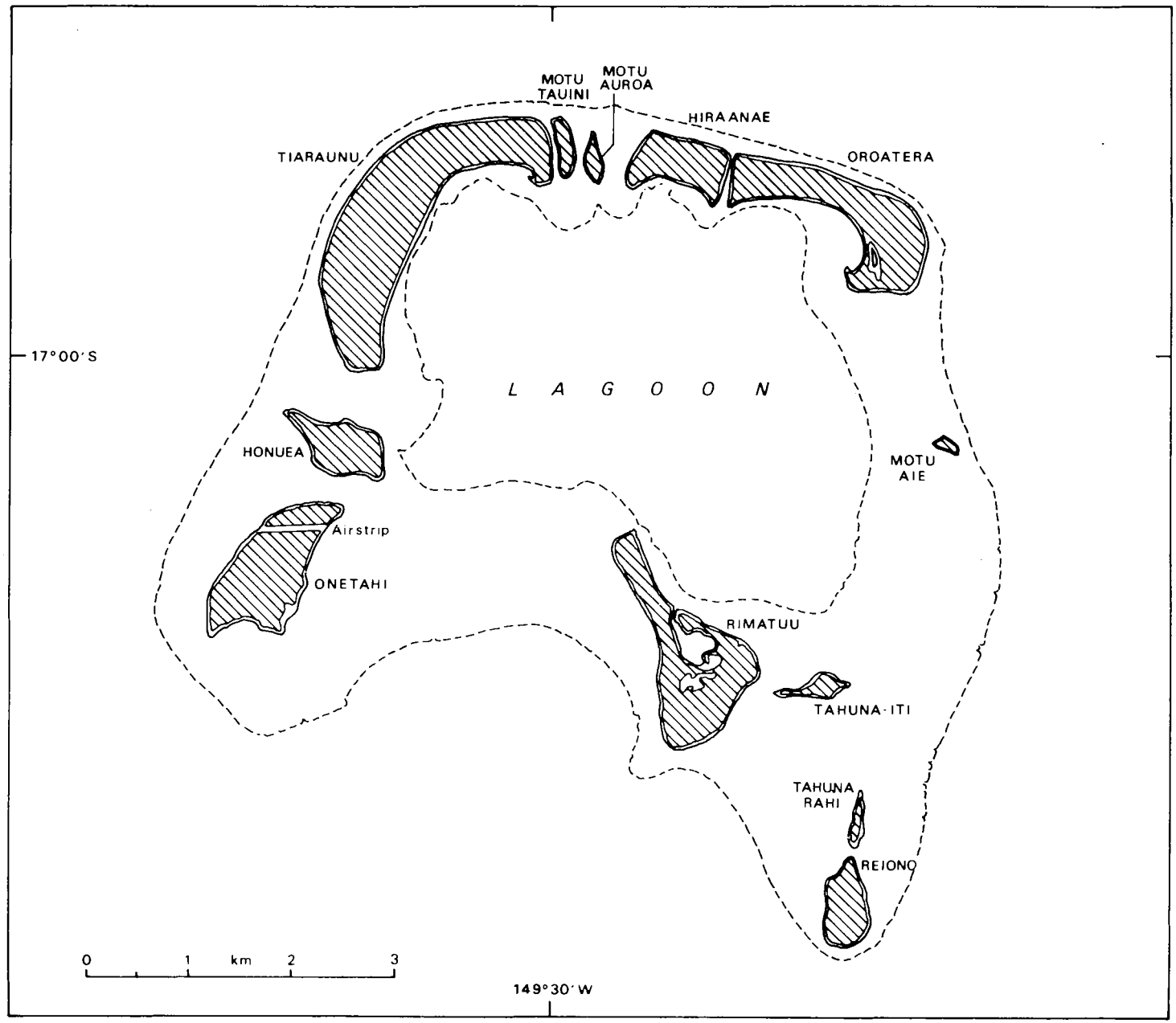

Fig. 1. Tetiaroa Atoll.

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PREFACE

This paper is a somewhat revised and updated version of a report, written in 1973 after our 9-day visit, at the request of Mr. Marlon Brando, proprietor of Tetiaroa Atoll, and published here with his accord. The original version was based on that visit to the atoll, as explained in the introduction. It was supplemented by a few observations culled from herbarium specimens and field notes of Dr. Gerrit Wilder, who visited the island briefly on March 12, 1925 and August 30, 1929, and of E. H. Quayle, of the Whitney Expedition, who stopped there on November 19-21, 1921.

In 1974-1975, at the turn of the year, one of us (Sachet) paid a second visit, during a very rainy period which limited work, especially collecting. In 1982 we paid a third visit of three days, July 27-29, and in 1983 one of us (Sachet) again visited it in March. All of our visits were made possible by Mr. Brando and his staff, to whom we are most grateful. We wish to remember especially Reiko Sato's help. Her knowledge and understanding of the atoll were remarkable and her long stays there provided a valuable continuity in observations.

The report has been revised to note some changes, additional plant records, and other observations, but still retains the character of information, comments, and recommendations that might be useful in the management of the atoll. We are glad to note that, notwithstanding the greatly increased number of tourist visits, only the areas in the vicinity of the Visitor Center, on the north third of Onetahi Islet and on Honuea Islet across a narrow channel, have been conspicuously changed from their condition in 1973, and some recommendations have been successfully implemented.

For this revision we have also had the benefit of information gathered by several visitors, not available to us in 1973.

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During his 14-months stay in French Polynesia (1949-1950), R. Papy visited Tetiaroa and gave a brief description of its vegetation (1956: 178-179). J.-N. Maclet spent Aug. 23-24, 1972, there and a list of trees, shrubs and herbs was prepared for the Service de l'Economie Rurale. Shortly after our March 1973 survey, Jean Raynal, of the Paris Herbarium collected plants - including some we had missed (June 27-29, 1973). Finally, just before our July 1982 visit, J. Florence with M. Guérin made a quick visit and collection. We have seen only part of these specimens.

The references listed at the end of the text do not all specifically deal with Tetiaroa, but some of them are principal general sources of information on atolls that might be of interest to readers wanting to know more about these fascinating bits of land.

I. INTRODUCTION

Late in 1972 Mr. Marlon Brando, owner of Tetiaroa Atoll, spent several hours at our office in the Smithsonian Institution with some of his advisors, discussing coral atoll ecology and his plans for the development of Tetiaroa Atoll in particular. As a result of this conference a short reconnaissance visit was arranged to give us some familiarity with the island as a basis for possible future ecological and botanical consultation. This visit lasted 9 days, from March 19 through March 27, 1973. All of the 13 vegetated islets were visited one or more times, and walked over to get a reasonable idea of their ecological features. The notes on vegetation features and collections of plants are the most complete, though a few land animals were noted or collected. Time did not permit a thorough examination and sampling of soils, as had been hoped, nor were the fresh and brackish water bodies, or the ground water, studied as intended.

The present report summarizes factual observations, impressions, and suggestions. It cannot be regarded as anything near a complete description of the atoll, except for the lists of vascular plants, which are probably nearly complete.

The comments and suggestions regarding human activities, management, and future development on the atoll were written for the use of Mr. Brando and his associates, but may still be of use as guides for management of the scores or hundreds of atolls and other coral islands that may be used for human occupation in the tropical seas. The descriptive and natural history portions have been revised and substantionally added to. Their publication will augment, somewhat, the general information available on terrestrial aspects of coral atolls. We deeply appreciate this opportunity to become familiar with one more atoll.

Certain shortcomings in the present report are the result of our failure to receive, in time for use in the field, the promised air photos that would have enabled us to make better use of our time, and to prepare a preliminary ecological map of the atoll. Under the circumstances we have not attempted to map any of the features of interest, but would recommend that an ecological map be prepared as the project is continued. It would serve as a guide in designing and implementing plans.

Historical background: The early history of Tetiaroa is obscure, perhaps expressed only in the legends of Tafai, who, it is said, drew all the islands in the region up above the surface of the sea.

In historic times Tetiaroa belonged to the Pomare family, rulers of Tahiti. They placed it in the care of faithful retainers, who managed it and lived there. The members of the royal family spent time there when they needed quiet and relaxation. The feminine members of the family are said to have gone there and "indulged in the art of ha'apori (fattening)... for the purpose of beautifying their person." The king placed his treasures there for safe-keeping during times of political trouble. "In times of peace, Pomare I sometimes held his heathen orgies while Tahiti was becoming Christianized." Tessier (1962) provides this information, in great part based on Henry (1928: 26).

Tetiaroa must have been known to early European navigators and Capt. Cook sailed by it on July 14, 1769. In 1904 the atoll was sold to Dr. Williams, of Papeete, who managed it as a copra plantation, with a small village on Rimatuu Islet where the labor force lived and where the copra was dried.

Mr. Marlon Brando acquired the island in the 1960's, and at first attempted to maintain the village on Rimatuu. The "nono" (Culicoides flies), which breed in brackish shores, as around the pond or "inner lagoon" on Rimatuu, proved very troublesome, and when his plan to build a tourist attraction was to be implemented, he moved his activities to Onetahi Islet. Here a landing strip was constructed and the present visitors enterprise is centered.

II. TETIAROA--ECOLOGICAL SETTING

Tetiaroa is a small atoll about 35 miles from Tahiti, in the Society Islands. It is thus within easy access from the larger island and metropolis of French Polynesia. This has been so since man first came to the Society Islands, which fact has had an enormous bearing on the ecological history and present ecological condition of the atoll.

The greatest diameter of the atoll is about 8.5 km and the periphery of the outer reef is about 28 km.

Thirteen vegetated islets are scattered on the reef ring, varying from a tiny remnant of reef platform less than half a hectare in extent to Tiarauna Islet, 205 hectares.

Surface features: The total land area is 645.5 hectares, reaching an elevation of not over 3 m. The deeper part of the lagoon is about 1288 hectares in extent, but a broad zone surrounding the islets is very shallow, apparently comprising wide coalesced sand aprons or fans. This entire area of apron, 2155 hectares, seldom exceeds 1 m in depth. It is of fine lime-sand and silt, with occasional coral fragments and many shells. Tiny clumps of coral (Acropora cervicornis) are scattered over it. It is very narrow only along the north side of the lagoon.

There are no boat passes into the lagoon except a very shallow one near the south end of Rimatuu Islet and a very small shallow one opposite the south end of Tiaraunu Islet. The east reef is largely free of islets and water enters the lagoon from waves breaking over the reef-edge.

The deeper parts of the lagoon are liberally beset with coral pinnacles and patch reefs, many of these reaching the surface at low tide.

On the outer reef platform are numerous remnants of one, or probably two, higher reef surfaces. They vary from small rocks and coral "mushrooms" to undercut platforms many meters long. Most are about 1 m high above the reef flat, but a few are about twice as high. Only one of these was examined and its surface was found to be very rough. Most of them are not vegetated except for darkening of surfaces by microscopic blue-green algae. A very few have scrubby Pemphis acidula.

Remnants of the 1 m platform, some eroded to much less than this, extend a short distance from the seaward sides of some of the islets, especially along the north shores of the islets on the north reef. Beachrock is found here and there along the shores of some islets. Its extent could not be mapped in the time available without air photos.

Peripheral ridges occur around most parts of most of the islets, especially on the seaward side, where they tend to be of pebble-, cobble-, or even, locally, boulder-gravel. Elsewhere, especially on lagoon shores, they tend to consist of sand or fine gravel. On some shores they are lacking altogether, while on some seaward shores they are very wide and gently sloping. Locally they are being cut away by waves, and in some such places, as on the northeast point of Onetahi Islet, trees are undermined and fall into the shallow water. The surface in the interior of the larger islets is generally of sand or small gravel; in places a sparse layer of pebbles lies on a surface of sand or mixed sand and gravel. No layers of phosphate rock were noticed, but, judging by the abundance of Pisonia grandis trees and of sea-birds, it doubtless occurs locally (see Fosberg 1954, 1957, Fosberg and Carroll 1965).

Rather extensive depressions occur on some of the islets, mostly with a soft organic soil and dense stands of saw-grass (Cladium jamaicense). They may have been ancient taro marshes, excavated by the Polynesians. This view is strengthened by the presence, adjacent to such a marsh on Honuea Islet, of irregular mounds of fine earth, possibly excavated from the marsh. In one such depression on Reiono Islet in rather dense coconut forest, this one lacking saw-grass, were a few plants of puraka or giant taro (Cyrtosperma chamissonis), possibly persisting from Polynesian plantings.

The soils of the islets varied from typical Shioya Series, scarcely altered coral sand and gravel, to soils with a black highly organic surface layer or A horizon, and to the deep organic muck of the putative taro pits mentioned above. No real study of these soils was attempted. One pit already dug to about 0.5 m, on Onetahi Islet, showed a typical Shioya profile about 40 cm deep, then a buried fine-textured darkened layer.

A rather extensive lake or pond of brackish to fresh water occurs on Rimatuu Islet. Maps show it to be open to the sea, but it seems closed now.

Climate: Tetiaroa is a moderately wet atoll, with an annual rainfall of about 2800 mm, but this tending to be somewhat irregular in distribution, with occasional dry spells.

Tetiaroa is in the belt of the Southeast Trade Winds, which generally make the temperature rather pleasant, except in the shelter of the coconut plantation and other dense vegetation. During occasional periods of calms, as in March, the temperature can be oppressively hot and the humidity high. Weather data are almost lacking and should be collected to substantiate present estimates.

A short series of rainfall measurements, covering the period February 23 to Dec. 31, 1974, was recorded by Reiko Sato. The total recorded was 1687.5 mm, with the lowest amount, 19.0 mm, for September, and the highest, 654.8 mm, for December. March, October, and November, each had between 100 and 300 mm. Some measurements may have been recorded in more recent years by resort personnel, but we do not have any of the figures.

Several storms have hit Tetiaroa since 1973. It does not take a full-fledged hurricane to create havoc on a low island. In Dec. 1974 heavy rainfall brought about flooding, especially in the area of the Visitor Center where the low buildings were awash. On New Year's Eve and New Year's Day, residents and visitors stood ankle deep in water and sand. The water receded fairly quickly and plants, except for some exotic ornamentals, didn't suffer too much from the effects of salt.

Some buildings were undermined and construction on the atoll set back.

By July 1982 it was obvious that the coastline along the channel between Onetahi and Honuea was especially vulnerable to erosion, it had receded conspicuously from its 1973 position. In the first 4 months of 1983, an unprecedented series of hurricanes hit French Polynesia, some reaching Tahiti. Residents and visitors on Tetiaroa were evacuated several times. Sachet's visit on March 20-21 followed hurricane Reva (Rewa), and by then many of the buildings on Onetahi had collapsed, lost their roofs, or been almost washed into the channel where erosion had scoured the coast line. On one of the "bird islands", Tahuna-iti, the low sandy part of the island had been flooded, many birds killed, trees defoliated or uprooted. The inside of the islet, however, had not been under water and the ground cover of grass and herbs was unchanged under the tall trees some of which had lost foliage or branches.

From Tahuna-iti, one could see in the distance some defoliated shore shrubs on Tahuna-rahi. The very low western tip of Tahuna-iti seemed cut off as a sand bank and all its vegetation dead.

The sea breached the sand bars which separate the sedge marshes from the lagoon on Rimatuu islet, mixing sea water into the brackish and locally fresh water. This phenomenon may be a recurrent occurrence, as the east coasts of Rimatuu have been variously described or mapped with or without openings onto the lagoon.

Honuea islet could not be visited, but appeared to have suffered from flooding, at least along the channel side opposite Onetahi.

Generally, prolonged flooding by sea water, with relatively little rain, and damage to buildings as a result of erosion and strong winds were the most striking effects of this hurricane. Most of the exotic ornamental plants had disappeared. Tall trees, including coconut palms, appeared relatively little touched, at least as far as one could see in a visit of a few hours.

After Sachet's departure from French Polynesia, hurricane Veena (April 8-13) caused much damage in Tahiti and may well have further devastated Tetiaroa, but no detailed information has been received.

Ground water: A lens of fresh ground water exists about 1-1.5 m below the surface of the ground on the larger islets. This is potable but rather hard water. In places it has a noticeable hydrogen sulfide odor, perhaps originating in the organic muck of ancient taro pits, or possibly, in some areas, from recent pollution. During rainy periods, fresh water seeps through the beaches from the periphery of this lens.

Vegetation: The vegetation of the islets has been profoundly altered by man, both Polynesian and European. The Polynesians certainly introduced the coconut palm, but did not plant it generally to form large plantations. More likely it was planted only around dwelling sites and to the extent that the nuts were needed for food and drink. The Polynesians probably, as noted above, excavated substantial areas for marsh cultivation of taro. Their extensive use of the native plants most likely did not result in serious change in areas of indigenous forest away from dwelling or other sites. They certainly brought some additions to the flora, beside the coconuts, plants such as Morinda citrifolia, Hibiscus tiliaceus, Gardenia taitensis, Tacca leontopetaloides, Cyrtosperma chamissonis, and probably others.

With the purchase of the atoll in 1904 by a European and possibly even earlier, coconuts were planted for copra production on all suitable, and some not so suitable, parts of the islets. The native vegetation was almost completely replaced, though most of the plant species may well have persisted.

Little can be said about the original vegetation, except that it was undoubtedly mostly forest, either dense or sparse, with some areas of scrub, possibly occasional openings with grasses, Boerhavia and Portulaca. On areas of bare coral rock or very thin soil a dense scrub of Pemphis acidula must have predominated, even as it does today. The forest was probably mostly very mixed in its composition, possibly with areas of pure stands of Pisonia grandis and, perhaps, groves of Hernandia sonora. Most of the present indigenous herbaceous species may have occurred in the forest, in openings, and around the tops of beaches.

Now the predominant vegetation on all but the smallest islets is coconut plantation, with a liberal mixture of trees, especially Guettarda speciosa, which have grown up with the decline of activity in the plantations. Harvesting of nuts was abandoned several years ago and coconuts falling on the ground and germinating have produced a prominent shrub layer of seedlings about 1.5-2 m tall in large areas of the plantation. Openings and thin areas in the plantation are occupied by Boerhavia, Lepturus, and Portulaca. A strong component of the shrub layer is Timonius polygamus. Suriana and Scaevola fringe the beaches and extend inland to some extent. The edges of the coconut plantations are filled with Tournefortia and Guettarda. Within the plantations Polypodium scolopendria, and more locally, Asplenium nidus, Davallia solida, Nephrolepis, Tacca, Triumfetta procumbens, and still more locally, Thuarea involuta, and Lepidium bidentatum form the herb layer, in places covering the ground completely. A liana, Ipomea macrantha, climbs in the trees. Nervilia is a rare and local ground orchid. Laportea ruderalis, and Psilotum are also occasional, either on the ground or on bases of coconut trees.

Dense and extensive stands of Cladium cover most of the ancient taro depressions, both in the open and under coconut trees, and also on the south side of the brackish lake on Rimatuu Islet. On Tiaraunu Islet, near the lagoon side, a large area of such marsh was originally under coconuts, but these have mostly died, leaving old headless trunks, and parts of the resulting open area have become dominated by Timonius and Scaevola scrub, with some tall Suriana on drier spots. Much of the marsh is covered by saw-grass (Cladium).

Peripheral areas where the islets are narrow, or on small islets, may be dominated by Suriana, mostly covered by a blanket of Cassytha, which in places seems to have killed its host, as an unusual amount of Suriana is dead. Where such areas have very thin soil or are exposed coral rock, Pemphis may be dominant forming a somewhat loose scrub, several meters tall, or a lower, very dense, almost impenetrable scrub.

On tiny Motu-Aie, and locally on one or two other small islets, a mixed forest of Pisonia, Guettarda, Cordia and Tournefortia survives, possibly similar to the original mixed forest but of rather low stature. Only a few coconuts have been planted on Motu-Aie. In 1982 these were seen to have been cut down leaving this islet in a natural condition. In at least two places, on Onetahi and Rimatuu, groves of Hernandia reach a very large size. Locally, especially on lagoon shores, thickets of Hibiscus tiliaceus and of Cordia subcordata occur. One small patch of Sophora tomentosa was found in the plantation on Hiraanae Islet. On Tiaraunu, local clumps of Pipturus argenteus occur well inland.

In sparse places in the coconut plantation and the west point of Honuea Islet, shrubs of Hedyotis romanzoffiensis characteristic of the Tuamotu atolls to the north and east, were common. Digitaria stenotaphrodes, also found in the Tuamotus, occurs in sparse vegetation on the south end of Tiaraunu and along the top of its seaward beach, also in the forest on Tahuna-iti Islet.

Around the two active camp sites on Onetahi and Tiaraunu islets (1973), several species of presumably planted trees have reached small-tree size: Terminalia catappa, Terminalia samoensis, Hibiscus tiliaceus, Casuarina equisetifolia, and Calophyllum inophyllum. These were fairly large in 1982 but T. samoensis was in very poor condition.

A number of exotic herbaceous weeds are found here, also, such as Cenchrus echinatus, Eragrostis tenella, Hippobroma longiflora, and Euphorbia hirta.

Around the abandoned village on the west side of Rimatuu Islet are many very large trees of Cordia subcordata, Artocarpus altilis, Calophyllum inophyllum, Terminalia catappa, and Hibiscus tiliaceus, as well as Cocos and one large Pometia pinnata. Many shrubs, such as Gardenia taitensis, Morinda citrifolia, Acalypha wilkesiana, Polyscias guilfoylei, Codiaeum variegatum, Citrus aurantifolia, Plumeria rubra, Pedilanthus tithymaloides, Hibiscus (double red hybrid), Carica papaya and Chrysophyllum cainito persist from former plantings. Here also are many weeds, some not seen elsewhere on the atoll, such as Bidens pilosa, Conyza bonariensis, Euphorbia hirta, Vernonia cinerea, Cyperus kyllingia, Cenchrus echinatus, Eleusine indica, Eragrostis tenella, Digitaria radicosa, and Sporobolus fertilis. Sida fallax, of the green-leafed large flowered form planted by Polynesians, is common in the plantation outside the village. In 1982 several weeds only seen on Rimatuu in 1973 had spread to Onetahi. Also Waltheria indica, not seen in 1973, had appeared and was abundant in the village site on Rimatuu.

In a very brief account of Tetiaroa, Papy (1956) offers a short characterization of the vegetation of Rimatuu Islet, which appears to be the results of one walk across from the lagoon beach to the "inner lagoon", dividing the vegetation into four "zones". These only vaguely suggest the distribution of the vegetation, and need not be considered seriously as reflecting either the pattern or the diversity of Tetiaroa, or of Rimatuu Islet.

III. ECOLOGICAL OBJECTIVES

After talking with Mr. Brando and Mr. Judge, reading the master-plan, and trying to think in ecological terms of what was said, we have attempted to formulate the ideas expressed in the form of a list of long-term ecological objectives. These aim to provide a set of scientific policy criteria under which proposed actions can be judged. If followed, these may make it possible to carry on the human objectives of the Tetiaroa enterprise over a long period, leaving the atoll relatively unimpaired in its capacity to support human life and activity and to satisfy human needs.

The objectives are as follows and seem to require no explanation:

1. To maintain the natural diversity of the living component of the Tetiaroa Atoll ecosystem.

2. To maintain the natural beauty of the atoll setting.

3. To avoid the depletion or impairment of any resource of the island on which man or other organisms inhabiting the atoll depend.

4. To avoid the accumulation, over a short term or long, of substances or waste products deleterious to life--human or other forms.

5. To avoid having any species of organism increase seriously in numbers at the expense of other species--in other words, to maintain an ecological equilibrium or balance.

6. To eliminate or reduce to reasonable numbers such exotic species as have been introduced and established in the past and have assumed pest proportions or threaten to do so.

7. To avoid introduction of exotics that may make life more difficult, less pleasant, or may disturb seriously the ecological equilibrium of the atoll, or pose a threat of disease.

8. To determine, and not exceed, the long-term carrying capacity of the atoll for humans in terms of the above stated objectives.

The last (no. 8) is, of course, the basic one, as violation of it will result in a spiral of environmental degradation that, if allowed to continue, will make the atoll unfit for habitation or only fit to serve as a platform to which can be brought the resources needed to support a very artificial sort of human existence.

IV. PRESENT STATE OF KNOWLEDGE

Factual information that contributes to an ecological understanding of the Tetiaroa ecosystem is rather meagre.

We have a certain generalized body of knowledge of coral atolls that permits some basic understanding of any atoll or coral island. This experience has been gained over a long period of years through the efforts of many people. It is nowhere summarized adequately. A great deal of information was assembled by Wiens (1962), but it was not reliably synthesized nor were his conclusions completely satisfactory.

Section II of this report offers a description of the superficial features of the atoll, especially the land geomorphology and vegetation, based on our own incomplete observations. This can and will be augmented from the study of air-photos when they become available. However, a detailed description remains to be written.

A reasonably good knowledge of the vascular flora is now available, though little quantitative information on the occurrence of the species is on hand. Only a superficial knowledge of the vegetation is on record and no vegetation map, even of the most schematic sort, is available.

Except for the birds, almost nothing is known of the animal life. We collected a few land crustacea, two lizards, and a few insects and spiders and are awaiting identifications of these. Four manuscript reconnaissance reports on the birds have been prepared by J.-C. Thibault, giving a pretty good idea of the present bird fauna and its occurrence on the islets of the atoll. Notes on the visit and collections of the Whitney expedition in 1921 are preserved in the American Museum of Natural History (Quayle 1922).

Little is on record on the behavior of any of the animals. Several of them have assumed pest proportions, but their life histories, habits, and behavior on Tetiaroa are not at all adquately known.

The fresh and brackish water hydrology are known only in a theoretical way, with very few samples and far fewer analyses. Nothing is known of ground water fluctuations and movements. Even rainfall figures are only extrapolated from Tahiti, except for the short series of records by Reiko Sato mentioned above, and records that we have not seen, said to have been made during Mr. Brando's project in the early 1970's.

No soil map is available and only the roughest observations have been made as to the soil types found on the islets. No soil profiles have been recorded.

Two reconnaissances have been made of the archeological sites, one by P. Vérin, R. Tessier and H. Picard about 1961 (?) (Vérin 1962), the other in December 1972 by Dr. Y. Sinoto (1974), of the Bishop Museum, Honolulu. Many sites are known that should be excavated or at least protected. Some excavating was done by Dr. Sinoto and his students in the 1970's.

The marine biology of the atoll is almost unknown, but recent surveys by Dr. John Randall and Dr. Harold Rehder, as well as those proposed by Dr. Bernard Salvat and his associates from the Paris Museum will remedy this lack.

V. PRIORITY REQUIREMENTS FOR FURTHER INFORMATION

It is almost a truism that the more complete the available information on an ecosystem the better the possible understanding of it. The gaps in recorded information are outlined above. Certain kinds of information may be more urgently needed than others, especially in view of the fact that development and change have already started.

The basic elements of the terrestrial ecosystem are the climate, rock and soils, water, vegetation, and fauna. Weather information must be collected over a considerable period before an adequate account of the climate can be prepared. Therefore, a matter of first priority is the establishment of a simple weather station with recording instruments, and with a reliable arrangement for changing the belts on the drums and keeping the records.

Advice on the best equipment available should be obtainable from the meteorological service in Papeete, or from the U. S. Weather Bureau of NOAA. It would be worth-while, in addition to standard weather observations, to make some records of microclimatic data, such as soil temperatures, temperatures near the ground in dense and open vegetation, wet and dry bulb readings, and temperatures in full sun, as well as temperatures in the sea close by, on the reef flat, in the lagoon, and in the surrounding open sea.

A related investigation that should be carried out would be to determine the amounts of salt spray that enter the soil and ground water at different distances from the windward beaches.

We would suggest a study of the soil types, with descriptions of representative profiles, correlation with physiographic features and vegetation, and a map showing distribution of profile types and textures. This probably could not be done well by an ordinary soil scientist, as atoll soils are very different from well-known continental or high island soils. Experience with atoll soils is limited to a very few people, principally Tercinier, E. L. Stone, Piggott, Hatheway, Catala, and Fosberg.

Ground water lens characteristics are one of the most essential sets of information on any island, and especially on coral islands. While certain general principles apply, the subterranean structure in limestone islands varies from island to island and even from place to place on the same one. The ground-water body in such an island behaves as a Hertzberg lens of fresh water floating on the salt sea-water, held by the friction with the porous body of rock and loose sediment. The porosity of these limestone accumulations

varies enormously, and on this depends the salinity of the water, though it is also influenced by rainfall regime, the tide range and exposure to wind waves. The texture of the sediments controls the stability of the lens itself, the time required for renewal, as well as the ease with which the water may be polluted. These are not easy things to determine directly, as it would involve drilling a considerable number of holes, to a considerable depth. It would be more economical to get salinity or chlorinity determinations of water samples from all the soil pits and/or auger holes dug during the soil study. On the basis of these a selection could be made of spots for sampling wells for a study over a longer period.

With a selected 3-4 protected wells (lined pits or driven points) on each of the larger islands where any development is planned, sampling could be carried out seasonally and related to storms, high winds, and periods of heavy swells, as well as intensity of human use. Chlorinity or conductivity determinations, which can be made locally with very little apparatus and by anyone with a little training, could be used to determine the seasonal and shorter term fluctuations in salinity. The same sampling could be used detect certain types of pollution. The odor of the samples should be noted immediately as they are taken. Any suspected pollutants, such as detergents, could be analyzed for.

A study of the vegetation might well be carried out simultaneously with the soil survey, as the boundaries of the vegetation types tend to correspond to certain of the soil types. Because the vegetation controls some other aspects of the ecosystem, or at least is correlated with them, a description and map of the vegetation are a guide to other features and an aid to understanding the system's functioning.

The remaining related group of investigations that seem rather immediately important concern the fauna. Life histories and breeding places of the animals that have multiplied to pest proportions--rats, flies, mosquitoes, and "nonos" (Culicoides) -- should be studied immediately. Surveys of the insects and other land arthropods, as well as the other soil fauna, should be undertaken to find out what species are present, what are their habitats, and what are their roles in the ecosystem. Since this report was originally written several entomologists from ORSTOM (Papeete) and l'Institut Malardé have carried on investigations of certain insects on the atoll, particularly Culicoides. We have not had the results of these studies. This zoological information, even more than the other categories outlined above, would also be of general scientific importance because of the poor state of knowledge of the terrestrial invertebrate faunas of coral islands.

Various other lines of investigation, especially those related to animal and plant parasitology, have much scientifc as well as practical value. Perhaps they can be regarded as somewhat less urgent than those described above. They could be done opportunistically, as people willing and able to do them happened to be available.

Following is an outline indicating the range of data required for a proper description and understanding of the atoll ecosystem, regardless of priority. Areas in which more nearly adequate data are available are not mentioned.

Data needed:

Detailed areas of islets (above any arbitrary datum)

Hydrography:

Currents around atoll and in and out of lagoon. Residence time of lagoon water. Temperature and salinity stratification in lagoon. Seasonal changes in temperature and salinity in lagoon and in surrounding water.

Meteorology--Climatology:

Daily and seasonal temperature, wind, rainfall, solar radiation regimes. Relative humidity and evapotranspiration. Incidence and strength of storms and hurricanes.

Geology, geomorphology, and soils:

Distribution of consolidated sediments--beachrock, phosphate, and elevated reef platform; elevation of same. Distribution, width, elevation, and texture of peripheral ridges; spits and bars. Maps of same. Distribution, elevation and texture of inland dunes and hillocks. Outlines and depths, as well as thickness, of organic layers in all inland depressions.

Ground water hydrology

Tidal fluctuation in level.
Source H_2S
Lateral movement of ground water.

Limnology:

Mapping of permanent, seasonal, and temporary fresh and brackish water; fluctuation in salinity; existence and depth of peat layers; core samples for palynological examination to determine role and history of human activity in the formation of these water and peat bodies. Invertebrate faunas of fresh and brackish waters and life histories of important organisms. Nitrogen fixation and organic productivity by blue-green algae.

Life histories and behavior patterns of land crustacea.
Their roles in reduction of organic debris and refuse.

Nature and roles of soil macrofauna and microfauna.

Soil microbiology.
Decomposition of organic material.
Nitrogen fixing by bacteria and blue-green algae.

Contribution from marine environment to land organic and mineral matter budgets.
Fish and other marine animals brought to land by birds and dropped there as excrement or refuse.
Marine algae and bodies of animals washed ashore and incorporated into soils.
Marine animals caught and used as food by humans (and their domestic animals).
Floating tree-trunks and other plant parts cast ashore.
Water falling as rain.
Salt spray blown ashore.
Skeletons and tests of marine calcareous animals cast ashore by wave action.
Pumice and other volcanic rocks cast ashore.

Detailed entomological and arachnological survey.
Faunistics
Life history and host relations.

Parasitology (terrestrial).
Plant
Bacteria
Fungi
Insects
Helminths

Animal
Protozoa
Bacteria
Fungi
Insects
Helminths

VI. PROBLEMS AND PROBLEM AREAS

Problems, by definition, are in relation to (or caused by) man. Some are the result of natural phenomena to which man has difficulty in adapting. Most of them result from perturbations in the environment caused by man. Man's inevitable effect on

the environment is to change it. The changes may be in the direction of improvement, but usually the result is degradation, often first noticeable as a process of gradual simplification and attrition of qualities important to man.

Our few days on Tetiaroa were sufficient to enable us to foresee certain of the problems likely to arise as the Tetiaroa master plan is carried out. For the most part we have no firm solutions to suggest, though we may discuss possibilities and possible lines of investigation as ideas worth trying. Ecology can furnish principles to serve as guides to avoid problems, and ecological research may suggest possible solutions, but a mere reconnaissance is seldom enough to find solutions.

Following are things that seem likely to come up. The order is not especially significant:

1. Water supply: This is likely to be a limiting factor to human activity on an island, even where the climate is wet. The ground water, though fresh and technically potable, is hard and very susceptible to pollution. The water table is very near the surface of the ground and the ground is very porous. Therefore anything poured or thrown on the ground will be washed down into the ground water. Although the Tahitians are a very clean people, personally, their habits otherwise are very much predisposed to accumulation of refuse in the vicinity of their dwellings. We consider, under present and likely circumstances, that pollution of the ground-water lenses on islands where there is substantial human activity is inevitable. For this reason, we suggest that a rainwater catchment for all cooking and drinking water is a must.

2. Sewage disposal: This is an inherently difficult problem on a small coral island if there is any sizeable population. The Polynesians in aboriginal times are said to have met the problem by defecation on the outer reefs where the tides took care of disposal. A modern sewer outfall, even if over the outer reef and if a pumping system could be built to compensate for the lack of gravity flow, would concentrate the sewage to an offensive degree.

The location of the Visitor Center is such that any practical sewer outfall would be so near the passage between Onetahi and Honuea islets that the sewage would be carried into the lagoon, where it would be a serious cause of pollution. Even if, as is likely, a septic tank system were built with an outfall into the sea, this problem would not be eliminated. The nature of the pollutant would merely be changed.

We have at present no suggestion to offer of a solution to this problem.

3. Solid waste disposal: Even the relatively minor activity now going on on the atoll produces a serious amount of non-biodegradable solid waste--bottles, tins, plastic containers, discarded items, etc. With the Visitor Center development, this would be multiplied many times. Burial of such waste , as well as of sewage, would result in pollution of ground water. (In 1982 it was being buried on Onetahi at some distance from the visitors center.) Taking it out to sea would be very difficult because there is no boat access to the lagoon. Dumping at sea would result in much of it being washed back onto the island.

The only thing we can recommend is some form of compaction and binding into non-buoyant packages that could be dropped into deep water.

4. Garbage disposal: The disposal of biodegradable refuse would be a simple matter of composting if it were not for the flies. They are attracted to refuse and breed in it. The present method of burying garbage, as well as human wastes, will inevitably result in water pollution.

Our only suggestion on this problem is a compost pit with an impermeable bottom, or a series of such pits, with covering plastic sheets to keep out the flies and elevate the temperature to hasten decomposition, this would necessitate regular and faithful attention. (See Composting, below).

5. Water pollution: Pollution of the fresh-water lens has been mentioned under each of the above problem areas, thus pointing out the principal sources of pollution. Another source, possibly as serious as those already mentioned, is detergent in dish-water and wash-water. These are now being poured on the ground. We noticed that excessive amounts were being used, several to many times as much as necessary. That the ground-water carries a considerable burden of detergent was suggested by a great amount of foam along the lagoon beach of Onetahi Islet, as well as an unidentified scum on the wet sand just above the water line.

That detergent is not the only pollutant is suggested by the presence, observed in 1973, along this beach, in very shallow water, of a narrow zone of a green alga, probably an Enteromorpha. Since we have no earlier observations it is not certain that this may not be a normal result of the seepage from the edge of the fresh-water lens with some nutrients from the decomposition of vegetation and the muck from ancient taro pits, but the growth seemed rather lush for that. The algal growth should be carefully monitored, as any significant increase in this alga is a good indication of rising nutrient level in the seepage from

the fresh-water lens, and a likely sign of pollution. In 1982 no such algae growth was seen on the lagoon beach, but some was seen along the passage beach near the staff residences.

6. Flies: The fly problem is directly correlated with human activity and that of man's domestic animals. Flies are attracted by odorous filth and garbage. They breed in fecal matter, human and aninal. Flies can be controlled in direct proportion to the elimination of these factors. Therefore the solution to the problem is directly dependent on the satisfactory solution of the garbage and sewage disposal problems mentioned above. These must, of course, be supported by changes in the personal habits of the people living on the atoll. It is strongly recommended that pigs, dogs, and other domestic mammals be strictly prohibited on the atoll. By 1982 all the pigs had been eliminated.

7. Rats: We have little direct knowledge of the rats on Tetiaroa, but indirect evidence suggests that they inhabit the larger islets in enormous numbers. We saw them on Onetahi around the camp and Oroatera in the forest, but cannot say which rat species they belonged to. Indications are that there has been a recent population explosion of a tree-dwelling rat. It is said they live in the crowns of the coconut trees.

There is an even-aged stand of coconut seedlings several years old, probably dating from the year after copra-making ceased, there are a few younger seedlings and germinated nuts, but no ungerminated ripe nuts on the ground, and no fully grown green nuts in the trees. The great numbers of half-grown nuts with holes gnawed in their sides, suggest that the abundant food supply, suddenly available when copra harvest ceased, encouraged a sudden increase in rat population. Demand for water caused the gnawing of half-grown nuts, which has now practically eliminated the supply of mature coconuts except on a few of the very small islets. The next phase may be a reduction in the rat population by starvation, but this will not be an effective control as long as garbage and unattended food supplies are available.

The rats must be brought under control for several reasons, among them the fact that they carry several serious diseases, but even more, their contribution to the mosquito problem. The coconuts with holes chewed in them are ideal breeding-places for mosquitoes, and their elimination would certainly mean a notable reduction in mosquitoes.

Man has been fighting rats for centuries, but to the best of our knowledge, never with complete success. The nearest to such an accomplishment that we know of was on Wake Island, where systematic poisoning with warfarin was the method used. However,

information from Michèle Darr suggests that warfarin will also kill crustacea, such as land crabs. This should be verified before the method used on Wake is adopted. If the land, hermit, and coconut crabs are susceptible, refinements of the method would be required, as these crustacea form a very essential link in several of the ecological processes at work on the atoll.

We would recommend the engagement of a specialist in rat-ecology, such as Dr. Barbehenn, Dr. Kasimir Wodzicki or Dr. Wm. Jackson, to make a careful study of the rat situation on the atoll. High rat populations simply are not compatible with either a tourist enterprise or the vegetable production project proposed for the atoll.

8. Mosquitoes: According to an earlier mosquito survey, there are three species of mosquito on Tetiaroa. One of them, Aedes polynesiensis, was locally very abundant at the time of our visit. It is a very annoying day-flying species. Another species was noticed at night, but not caught for identification.

We are not experts in mosquito control; however, we would not like to see the professionals in this field given free rein, because of their tendency to use the easy temporary solution of spraying with DDT. The plan to chop up the coconut trash for compost, in addition to reducing the rat population, will make a great contribution to mosquito control. Steps beyond this will depend on an adequate knowledge of the life histories and behaviors of the species present on the atoll.

One urgent caution has been indicated by Dr. Guy Loison, of the South Pacific Commission. This is the need for careful spraying of all planes landing on the atoll to prevent further introductions of mosquitoes, especially of Aedes aegypti, carrier of dengue fever, common on Tahiti but not yet introduced on Tetiaroa. This precaution cannot be too strongly emphasized.

9. "Nonos" (Culicoides): This tiny biting fly is found at least on Rimatuu Islet, but we did not encounter it. We do not know details of its life-history, but are told that it breeds in the edges of brackish water ponds. We would suggest that a careful study be made of its habits and breeding places. Every effort should be made to eliminate it, but without at the same time eliminating other animals. The Public Health Department of the South Pacific Commission may have much of the basic information needed in its files. We have been informed that Mr. G. Pichon, of ORSTOM, plans to work on this problem.

In any event, this is a matter that cannot be neglected or procrastinated about.

10. Noxious weeds: Not many species of weeds will thrive on atolls, but some are very aggressive even under saline conditions, and some are very annoying. Several weeds already introduced should be ruthlessly eliminated. Examples are Cenchrus echinatus (sand-bur), Bidens pilosa (Spanish needle), and Hippobroma longiflora (Star of Bethlehem). At present sand-bur is found only around Rimatuu Village and at the camp-site on Onetahi, and Spanish needle only at Rimatuu Village where it is very abundant (now also on Onetahi). The poisonous Hippobroma is only around the camp-site on Onetahi.

Great care should be taken in the introduction of new ornamental and food plants to the atoll: Some of the ornamentals might become naturalized and get out of hand, and, more likely, weeds, nematodes and injurious insects might be carried in the dirt on the plant roots. Promiscuous, uncontrolled plant introduction should be stopped. A certain amount of it was going on at the time of our visit. Plant diseases, also, may be brought in on plant materials.

11. Quarantine: A quarantine is sometimes difficult to enforce, but to avoid the introduction of further noxious insects, plant diseases, and weedy plant species, regulations seem necessary. It would be best to prohibit the bringing of any plants, animals, or soil except by the management, and then under strictly planned and supervised circumstances.

12. Composting: As inhabitants of atolls have known for many centuries, the best way to dispose of vegetable trash is by composting. The organic soil that forms the bottoms of the low areas on most of the islets of Tetiaroa undoubtedly persists from the time when these depressions were taro pits of the ancient Polynesians. In the Gilberts, where population pressure necessitates maximum productivity, to this day all leaves, weeds, drift material, anything that will rot, are thrown into the taro pits.

We would recommend, without hesitation, that a fairly extensive hole be dug down to the water table and that all vegetable material be placed in it. A black plastic sheet somewhat larger than the hole should be used to cover it and keep flies out. Several such holes will doubtless be required, even to dispose of trash from the camp, visitor center, Polynesian village, and vicinity.

Garbage of animal origin, such as fish offal, had best be accumulated in covered large containers and rafted to an islet where the ground water is not to be used, and a composting operation started there. After such nitrogenous compost is well rotted, it could be recovered and mixed with vegetable compost for gardening and taro culture. Any areas where vegetables or ornamentals are to be raised should be liberally supplied with compost, as atoll soils are mostly notoriously poor.

A question arises about coconut trash. Such trash as accumulates around dwellings and facilities should, of course, be thrown in the vegetable compost pits. Mr. Judge informed us that the general accumulation of coconuts, leaves and trash will be put through a mobile shredder or chipper. This will at the same time get rid of water receptacles that breed mosquitoes and provide abundant material for compost; this can merely be allowed to decompose where it falls, or be brought to central compost pits. The former solution will result in a certain amount of general improvement of soil, if fires can be avoided. The latter solution will provide quantities of compost that can be placed where it is needed.

Mechanically shredding the trash has the drawbacks that the machines make much noise and have high energy requirements. These matters will at least have to be given some consideration.

13. Coconut seedling underbrush: Since copra-making was suspended, a thick undergrowth of seedling coconuts has filled much of the space in the coconut plantations, forming a practically impenetrable tangle. This is unattractive and tends to choke out the normal indigenous vegetation. If the shredder is brought in and used, such seedlings can be grubbed out and run through it, effectively disposing of them. Some decision must, in any event, be made about them.

If the rats are reduced or eliminated, of course there will be a continuing new growth of seedlings, unless the coconuts are gathered and used, either green or ripe. Incidentally, recently germinated coconut embryos make a delicious food novelty that could be offered to tourist visitors.

14. Coconut lumber: We noticed that coconut logs are being sawed up for lumber in the construction of the Visitor Center. We wonder if the durability of coconut lumber, especially green, has been looked into. Our impression is that it may be fairly short-lived, as will the coconut-thatched roofs.

15. Reaction of birds to tourists: One of the attractions about visiting an atoll is to see large numbers of sea-birds. There are several places on Tetiaroa, on certain small islets, where boobies, terns and frigate birds may be seen in numbers, at least at certain seasons. A problem that must be kept in mind is that crowds of noisy tourists may very well drive off the birds and discourage future nesting. Advice should be sought from ornithologists familiar with sea-bird behavior as to how this problem may best be minimized. Our only suggestion would be to have not-too-frequent visits by small, carefully selected parties, well guided and supervised.

In addition to the above problems directly involving the terrestrial ecosystem, several marine problems are apparent. These will in all likelihood be considered by the marine biologists, but may be mentioned here for emphasis and in case they are overlooked.

1. Fishing: In 1973 we observed catching of fish and lobsters on a fairly intensive scale. Boats were at work practically every night. They were even towed around the lagoon by Project personnel and boats. This fishing seemed on a scale that could only be commercial. Sport fishing could be one of the attractions for visitors. However, commercial fishing would soon deplete the resource to the point where sport fishing would become unrewarding.

2. Attrition of reef life: As soon as tourists begin to come in numbers, they will want to do scuba-diving, with spear-fishing and shell-collecting as objectives. This will surely deplete certain of the reef organisms. Corals will be broken off and the more attractive mollusks, especially cowries, will be picked up. The larger bright-colored fish, too, will disappear, as will lobsters.

3. Possible appearance of Ciguatera: The configuration of the lagoon and lack of boat passes will surely create a strong temptation to blast passes, eliminate coral heads, and dredge boat channels and mooring areas. This should be resisted. It would alter lagoon ecology with unforeseeable consequences. More serious, however, would be the possible appearance of ciguatera, or fish-poisoning. It seems to be associated with exposure of fresh surfaces of reef-limestone and their colonization by poisonous blue-green algae, which are eaten by the fish. This possibility should be very seriously considered before any work in the lagoon is undertaken. Dr. John Randall is an authority on ciguatera, as is Dr. Bagnis, and his group at the Institut Malardé.

VII. LONG-TERM VS. SHORT-TERM SOLUTIONS

For some of the problem areas listed, solutions may seem rather obvious and easy. Often the easy answer is a short-term one that, while it may solve the difficulties at hand, may creat more serious ones. A permanent solution may be more difficult and costly. It is well to try to look at each problem ecologically, in all of its aspects and ramifications, and to try to anticipate possible consequences and side effects. The only way to be able to do this is to collect all possible information, to develop an understanding of the whole system, and to look on the things man does as perturbations with good or bad effects, depending on the nature and direction of the perturbation. Perhaps the best guide is wherever possible to get nature to work with the Project, rather than to force nature into a human-made mold.

VIII. ECOLOGICAL FEASIBILITY OF THE PROJECT

It is difficult, if not impossible, on the basis of a brief reconnaissance, to form any firm opinion on the ecological feasibility of a complex project such as the development of Tetiaroa. A few observations can be offered as guidelines.

Archeological evidence suggests that over a considerable period of time Tetiaroa supported a substantial population. It was obviously a satellite of Tahiti, but in all probability was largely self-sufficient, food-wise. Perhaps it even contributed to the support of Tahiti, judging by the extent of the ancient taro pits. There is no obvious change in the environment that would preclude support of a present-day population, but modern methods of exploitation of resources are so effective that, without discipline, over-exploitation is almost inevitable.

Even on modern terms, and assuming that much in the way of food and goods of all kinds, including the basic energy source, will be imported, discipline is one of the two keys to long-term feasibility. The other is developing an understanding of the ecological constraints in operation.

The assumption that the enterprise, after it is established and operating, will be self-sustaining imposes certain constraints. The most obvious one is that no serious physical discomforts or hazards be allowed to develop or persist. Such, if they occurred, would deter both tourists and employees from coming to or remaining on the atoll. The present abundance of flies, rats, mosquitoes and nonos may fit into this category. Loss or deterioration of the unique features that will attract tourists could prove fatal to the tourist portion of the project. Pollution or serious alteration of the properties of the lagoon water might do the same for the mariculture aspect. Therefore, the consequences of any major manipulation of the environment must be very carefully weighed.

The unusual geomorphology of the atoll, especially the lack of boat passages through the reef and the very broad shallow-water zone lining much of the lagoon shore, place serious constraints on possible tourist activities, though they may be very favorable to some aspects of mariculture. If these features had been taken into account, the choice of location for the Visitor Center might have been different. These is little possibility of good swimming near the present location. Some of the proposed use of rafts or barges may not prove feasible, and even boat activity will be limited.

Tourist activities must be planned with an awareness of these features and keeping in mind the dangers of ciguatera if substantial excavation or blasting should be undertaken to change the lagoon configuration or open up channels.

A modest, well-planned facility, designed for a selected and limited class of tourists is certainly ecologically feasible, if the above constraints are borne in mind. This assumes, of course, that the existing pest problems are solved and that no new ones are created by careless introduction of organisms. It also assumes that pollution can be kept to a minimum.

It is our opinion that any large scale tourist development will fail, unless it is of such a character as to involve total alteration of the environment and provides almost complete insulation of the tourists from the natural environment. And under these conditions we do not see any special reason for tourists to come to Tetiaroa.

IX. IMMEDIATE PRACTICAL SUGGESTIONS AND RECOMMENDATIONS

In general, it is inadvisable to make recommendations on the basis of a short reconnaissance. However, there are a number of suggestions that seem appropriate on an immediate, short-term basis. These are neither of equal importance or organized in a completely logical fashion, nor are they mutually interdependent. Some are intended to correct conditions and practices observed to be wrong or detrimental, others to provide for future needs of the project, others to help determine future activities.

1. Institute spraying of incoming planes immediately.
2. Stop, at once, the pouring of wash-water and dish-water containing detergents on the ground.
3. Get rid of pigs and dogs.
4. Construct and operate fly traps.
5. Tighten up garbage and sewage disposal procedures.
6. Start composting operation.
7. Break up rat-chewed coconuts to eliminate mosquito breeding places, either using a shredder or chopping them with machetes.
8. Get expert advice on rat ecology and control.
9. Carry out a thorough limnological investigation of the brackish-water lake on Rimatuu, preliminary to planning for control of "nono" (Culicoides).
10. Make a survey of intensity of salt spray at different places and under different weather and sea conditions.
11. Build a water-catchment and water storage tanks to supply soft, safe drinking and cooking water. This should provide ample capacity for the size of population expected in the forseeable future.
12. Pull up and burn all plants of sand-bur (Cenchrus) beggar's ticks (Bidens pilosa), and star-of-Bethlehem (Hippobroma), and continue to do this at intervals short enough so that these plants do not set seeds.

13. Prepare list of available ornamentals that might be used for planting around the Visitor Center and other installations, submit it to us to check if any reasons are apparent for not importing some of them.
14. Check all possible habitats--coconut shells, fallen coconut bracts, crab holes, tin cans, and other receptacles, as well as standing water in low spots--for mosquito larvae. Preserve in alcohol samples of larvae from each habitat checked for species identification.

X. HUMAN RELATIONS

This is an important but difficult field of scientific study. Someone in close contact with the project should have as one of his duties to keep a log of all human events--arrivals, departures, illnesses, accidents, quarrels, cooperation, lack of it, alcoholism, personal friendships and liaisons to the extent that they can be observed, prevalence of gossip and rumor, violations of regulations, reactions and comments of visitors, complaints from residents and visitors, records of menus and of imports of foods and other items, as well as any other information bearing on human and social relations.

The interrelations between these things and the environmental factors and changes must be studied carefully and fully understood if any stable workable system is to be established.

XI. SUGGESTED LONG-TERM PROGRAM OF RESEARCH AND MONITORING OF ENVIRONMENT

The proposed development of Tetiaroa, deliberately planned so as to avoid the usual ecological mistakes, is an almost unprecedented experiment. For islands, especially coral islands, it is totally unprecedented. Hence there are no guide-lines to indicate what to do and what not to do, nor even to tell when mistakes have been made before it is too late to correct them. This project is therefore very important, as it may serve to establish such guidelines and be used as a model for other such developments. It may serve to demonstrate the practicability of rational development of islands.

For this reason, as well as to assure the success of the enterprise, itself, a program of research and continued monitoring of the environment is essential. Only by this means can sufficient understanding be developed to anticipate and deal with the problems that surely will arise, indeed, have in some cases already arisen. Basically, it is necessary to know what resources are available, what factors affect them, and at what rates they may be safely utilized to maintain a sustained "yield." We are speaking, here, of more than material, consumable resources.

Beauty, for example, is one of the most important resources on Tetiaroa. It is not consumable, but it is certainly destructible.

We have outlined a tentative program as a basis for discussion. Because the terrestrial and marine aspects are so closely interrelated, we have included some suggestions on the marine side, subject, of course, to modification and improvement in consultation with marine science collaborators.

The program is ambitious, and parts of it may be expensive. Some aspects, such as matters related to public health and sanitation might be of interest to public authorities, who are well-equipped to handle such investigations and concerns, as a part of their official programs in French Polynesia. We understand that a college may be established on the atoll. Many of the items listed below could be undertaken on a part-time basis by the faculty of this school, and some even as student research projects. A geology or geography student from a university might undertake the basic geomorphological work needed, in return for the opportunity to do work on an atoll. Dr. David Stoddart of Cambridge University might be willing to direct such a student. Further archaeological work might be appropriate, though much has been done by Dr. Vêrin and Dr. Sinoto. This might point the way to further excavations which could provide training for students as well as round out the knowledge of the Polynesian occupation of the island.

If serious scientific work is contemplated, a meeting of those interested in Tetiaroa might be arranged, preferably on the island, to discuss this tentative program and develop it into a workable scheme.

Of extreme importance is the establishment of a central file of copies of all information collected concerning the atoll. This should be in duplicate or triplicate, one set being with whomever is running the project, the others at stable permanent scientific institutions, such as the Smithsonian and Bishop Museum.

Research Program for Tetiaroa Atoll

Terrestrial aspects

-- Detailed description of atoll.

-- Procure air-photos if available.

-- Make cover type overlay.

-- Detailed study of relief, soils and cover types and correlation with air-photo overlays.

-- Detailed traverse of all shore-lines with mapping of shores showing rock vs sand vs gravel vs beachrock; erosion, deposition; slope of ramps and beaches; pot-holes and channels on ramps; any other shore features.

-- Complete inventory of plants and animals, with rough data on abundance. Repeated annually, noting changes in abundance, disappearance of species, appearance and establishment of new exotics.

-- Establish a network of permanent photo points, to be used at regular intervals to detect long-term trends.

-- At each photo point establish a permanent plot with plants mapped, to be remapped at regular intervals.

-- Establish, measure accurately, and map vegetation, psychrometer readings, and soils, of several carefully selected transects, to be restudied and remapped at regular intervals.

-- Establish a line of 4 or 5 wells across widest parts of 4 largest islands and several on other islands, these to be lined, above water-table, with concrete pipe or ceramic tile, and capped with removable lid. Water to be sampled at regular intervals and samples analyzed for salinity, hardness, bacteria, H S and other measures of water quality. Driven points could be substituted for wells if desired, at least in non-rocky areas.

-- Establish series of air-salinity points, to be checked at regular intervals.

-- Establish simple weather station to measure and record rainfall, temperature, relative humidity, wind strength and direction, solar energy amount and regime.

-- Careful description of the condition of coconut and other trees at photo-points, repeated at regular intervals.

-- Life history studies of animals of particular interest. e. g. mosquitoes, flies, nonos, hermit-crabs, land-crabs, coconut-crabs, etc.

-- Regular censuses of breeding birds.

-- As detailed a history of the atoll as possible from recorded and contemporary sources.

Fresh and Brackish Water Aspects

-- Detailed limnological survey of all permanent and temporary standing fresh and brackish water on the atoll, with life histories of abundant organisms, especially Culicoides and those suspected of being predators or parasites on it.

Marine Aspects

-- Detailed hydrographic description of lagoon and reef waters. Standard physical oceanographic study of off-reef waters around atoll, especially current data.

-- Plankton survey and analysis of waters around atoll and in lagoon, repeated at established intervals.

-- Complete inventory of benthic organisms on outer reefs and in lagoon, repeated at established intervals.

-- Establishment of several sets of transects across outer reef flats and fronts and similar ones across lagoon, with mapping of sessile organisms and depths, recording of free-swimming animals, transects to be remapped at regular intervals.

-- Water quality studies of lagoon water at regular intervals.

-- Food web studies of outer reef and lagoon reef faunas.

-- Annual pesticide and heavy-metal residue analyses of selected species of larger marine animals and sea-birds.

-- Periodic censuses of Acanthaster populations.

-- Establishment of a number of permanent underwater photo points, to be rephotographed at established intervals.

-- Regular counts of sea-turtle landings and egg-laying.

-- Periodic quantitative monitoring of green algae on lagoon beaches.

-- Monitoring of population increases and decreases of selected marine animal and plant species.

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APPENDIX I

List of indigenous, spontaneous and well established plant species.

This list includes all plants collected or observed by us and by other collectors, except for recently planted ornamentals or fruit trees whose survival seems somewhat doubtful. Most species were collected only once or twice, even though they occur on several islets (see Appendix II). Of our own collections, the first set is deposited in the U.S. National Herbarium (US) with duplicate sets at the B. P. Bishop Museum in Honolulu (BISH) and the Herbarium in Paris (P). Other specimens are cited from Royal Botanic Gardens, Kew (K), New York Botanical Garden (NY) and Brooklyn Botanical Garden (BKL). The herbarium symbols or abbreviations follow the Lanjouw scheme, Index Herbarium, adopted by the International Association of Plant Taxonomists.

An asterisk * placed before a name indicates that we believe the species to be introduced to the Society Islands by human agency (ornamentals, food plants or weeds).

FUNGI

Albugo platensis Speg. — White Rust

Motu-Aie Islet, Fosberg & Sachet 54625

Parasitic on Boerhavia tetrandra, producing erect, condensed, witches-broom-like branches.

Fomes sp. — Shelf Fungus

Oroatera I., Sachet & Fosberg 1688

Saprophytic on dead coconut trunks. Dark brown to black woody semicircular shelf-like fruiting bodies with fine pores beneath.

Schyzophyllum commune L. — Leather-gills

Motu-Aie I., Fosberg & Sachet 54622

Saprophytic on dead wood. Thin tough bracket-like fungus fruiting body.

LICHENES (all det. Mason E. Hale, Jr.)

Parmelia saccatiloba Tayl.

Onetahi I., Sachet 1672.

On coconut trunk.

Parmelia sp.

Onetahi I., Fosberg 54680.

Epiphytic on coconut trunks. Flat leaf-like greenish-white lichen.

Physcia sp.

Reiono I., Sachet 1661b.

A gray crustose lichen on tree-trunks.

Pyxine cf. chrysanthoides Vain.

Oroatera I., Sachet & Fosberg 1682.

A light gray knobby crustose lichen on coconut trunk on lagoon beach.

Pyxine cocoes (Sw.) Nyl.

Reiono I., Sachet 1661a.

A gray crustose lichen on tree trunks.

Pyxine retirugella Nyl.

Onetahi I., Sachet 1663.

A dark gray crustose lichen with black fruiting bodies on coconut trunk.

Pyxine sp.

Onetahi I., Sachet 1662.

A light creamy slightly greenish gray crustose lichen on coconut trunk.

ALGAE

Nostoc sp.

Onetahi I., Sachet 1657.

On bare moist sand along side of air strip. Dark greenish black amorphorus masses, gelatinous when wet.

Enteromorpha sp.

Onetahi I., Sachet 1677.

Forming a narrow zone on lagoon beach, just below mid-tide. Tufts of fine green filaments.

Trentepohlia sp.

Onetahi I., Sachet 1665.

On surfaces of tree trunks. Forming a fine bright orange fuzz on surface of bark.

MUSCI (all det. H. Robinson)

Brachymenium indicum (Doz. & Molk.) Basch & Lac. Moss

Rimatuu I., Fosberg 54580.

A small terrestrial moss forming thin cushion on coral sand in semi-open areas.

Calymperes tenerum C. Müll. Moss

Onetahi I., Sachet 1667.
Oroatera I., Sachet & Fosberg 1686, 1687.

A brownish or golden green epiphytic moss forming loose cushions on tree trunks.

Calymperes tuamotuense Bartr. Moss

Onetahi I., Sachet 1666.
Honuea I., Fosberg 54575.

A golden green epiphytic moss forming dense cushions on coconut trunks and their enlarged bases.

Leucophanes nukahivense Besch. Moss

Oroatera I., Sachet & Fosberg 1684.

Forming thick pale green cushions at bases of coconut trees and stumps.

Taxithelium vernieri (Duby) Besch. Moss

Oroatera I., Sachet & Fosberg 1685.

An extensively spreading slender green moss forming thin mats, especially on rotting coconut trash, in shade.

Trichostelum hamatum (Doz. & Molk.) Jacq. Moss

Rimatuu I., Fosberg & Sachet 54650.

A light green moss forming a thin mat on fallen Pandanus branch.

PSILOTACEAE

Psilotum nudum (L.) Beauv.

Onetahi I., Sachet 1637
Oroatera I., Fosberg & Sachet 54617
Rimatuu I., Fosberg 63765
Reiono I., Sachet 1641
Tiaraunu I., Raynal 18002 (P)

Occasional on bases of coconut trees and on coral boulders in shaded interiors of islets. Broom-like tufts of prismatic, dichotomously branching stems bearing large yellow spore-cases on sides of terminal branchlets.

POLYPODIACEAE (Fern family)

Asplenium nidus L. Birds-nest fern

Oroatera I., Sachet & Fosberg 1689
Tiaraunu I., Fosberg & Sachet 54647
Reiono I., Sachet 1643

On ground and bases of coconut trees in shaded interiors of islets. Also seen planted as ornamental on Onetahi and Rimatuu. Nest-like rosettes of ascending broadly lance-shaped undivided fronds, the fertile ones having a zone of pinnately arranged, parallel, crowded, linear fruiting sori on the under sides.

Davallia solida Sw. Fern

Rimatuu I., planted or persisting, seen by Fosberg in 1982.
Oroatera I., Sachet & Fosberg 1685
Tiaraunu I., Raynal 18004 (P)

On rocks and fallen coconut trunks in interiors of islets. Creeping stems with scattered triangular finely several-times divided fronds; spores borne in pockets along edges of segments of fronds.

Nephrolepis hirsutula (Forst.) Presl Sword fern

Tiaraunu I., Fosberg & Sachet 54615, 54648
Oroatera I., Fosberg & Sachet 54618

On ground in interiors of islets. Short erect stems above ground, bearing slender cord-like runners which bear the roots, and erect or ascending fronds with many pinnately arranged pinnae or leaflets that bear kidney-shaped spore-dots or sori on under surfaces, pinnae shed when old, leaving stiff persistent rachis.

Polypodium scolopendria Burm. f. — Lawai fern (Hawaii)

Tiaraunu I., Sachet 1679
Rimatuu I., Quayle 194 (BISH, BKL)

Abundant in shade on ground and on bases of coconut trees. Creeping stem or rhizome bearing scattered erect, long triangular-ovate deeply and coarsely pinnately divided fronds with two rows of brown fruiting dots or sori beneath, fronds shed from rhizome when old.

PANDANACEAE

Pandanus tectorius Park. — Fala; fara; screw-pine

Onetahi I., Fosberg & Sachet 54633; Raynal 18018 (P)
Tahuna-rahi I., Sachet 1650
Tiaraunu I., Sachet 1680
Honuea I., sight record by Sachet in 1974.
Rimatuu I., Raynal 18011 (P); Florence 3267 (P, US).

Generally distributed, especially on peripheral ridges of islets. Small trees, sparsely and grotesquely branched, pyramidal, branches thick, bearing 3 spirally twisted ranks of long, strap-shaped, prickly, tough leaves with slender whip-like points; male and female flowers on different trees, the male in long branched pendent catkins with white leaf-like bracts, odor rather unpleasant; female in globose tightly packed heads; fruits packed in a tight head-like cluster, 15-20 cm in diameter, individual fruits or keys lobed at apex, distal part hard and bony, lower half or third fleshy, orange, fragrant, acrid sweet.

GRAMINEAE (POACEAE) (Grass family)

*Cenchrus echinatus L. var. echinatus — Sand-bur

Onetahi I., Fosberg & Sachet 54630

Locally established in shaded area of camp on Onetahi, not seen elsewhere. Small tufted grass, bearing spikes of prickly unpleasant burrs. This form is smooth.

*Cenchrus echinatus var. hillebrandii (Hitchc.) F. Br.

Rimatuu I., Fosberg 54609
Onetahi I., Fosberg & Sachet 54646

Very local around old village and around camp. A form that is notably hairy rather than smooth.

*Cynodon dactylon (L.) Pers.

Onetahi I., Sachet 1676; Fosberg 63787; Raynal 18019 (P).

Planted and growing well and abundantly on airstrip. A close-growing, creeping, mat-forming, fine-leafed grass, with digitate fine flower and fruit clusters on erect stems.

Digitaria setigera Roth

Rimatuu I., Fosberg 63773

Rare, around ruins of old village.

Digitaria stenotaphrodes (Nees) Stapf

Tiaraunu I., Fosberg & Sachet 54616, 54649; Raynal 17998 (P).
Tahuna-iti I., Fosberg 63756

Scattered tufts in open scrub forest and along top of seaward beach. A stiff, tufted, erect grass, with stiff spikes of flowers and fruits, crowded in 3's or 4's at tops of erect stems.

*Digitaria radicosa (Presl) Miq. Crab=grass

Rimatuu I., Fosberg 54602, 54606, 54611; Raynal 18024 (US, P).

Locally established at top of beach and edges of old village. Depressed, spreading weak-stemmed slender grass with several slender digitate spikes radiating from ends of slender stems.

*Eleusine indica (L.) Gaertn. Goose-grass

Onetahi I., Raynal 18014 (P); sight record, Fosberg in 1982.
Rimatuu I., Fosberg 54593

Local in old village. Tufted, tough-rooted grass, with several broadly linear divergent spikes of flowers radiating from ends of stems.

*Eragrostis tenella (L.) Beauv.

Onetahi I., Sachet 1693b
Rimatuu I., Fosberg 54594
Honuea I., small patch seen by Sachet in 1974.

Local in old village and around camp. A fine, delicate grass with a diffuse feathery flower cluster.

Lepturus repens R. Br. Bunch-grass

Onetahi I., Raynal 18015 (P, US)
Honuea I., Fosberg 63779, 63781

Motu-Aie I., Fosberg & Sachet 54623
Rimatuu I., Fosberg 63769, 63771
Tiaraunu I., Raynal 18007 (P)
Tahuna-rahi I., Sachet 1645

Generally common or abundant. Tufted to creeping stiffish grass with long, awl-shaped jointed flower spikes, in fruit disarticulating into small cylindric floating segments, each carrying a seed. Found on all islets.

*Sporobolus fertilis (Steud.) Clayton

Onetahi I., Fosberg 63790
Rimatuu I., Fosberg & Sachet 54596; Fosberg 63774; Raynal 18022 (P)'

Local in old village. Tufted grass with long slender linear flower spikes.

Thuarea involuta (Forst.) R. Br. ex R. & S.

Oroatera I., Sachet & Fosberg 1690
Reiono I., Sachet 1638

Very local in shaded interior of islets. Creeping, mat-forming, broad-leafed grass with very short, few-flowered flower clusters on erect stems, and very small, fist-shaped fruits.

CYPERACEAE (Sedge family)

Cladium jamaicense Crantz — Saw-grass

Onetahi I., Sachet 1656
Honuea I., Fosberg 63782
Hiraanae I., in small water-hole, sight record by Sachet in 1974.
Rimatuu I., Wilder 955 (BISH); Quayle 195 (BISH); Raynal 18009 (P).
Oroatera I., Fosberg & Sachet 54619
Tiaraunu I., Fosberg & Sachet 54654

Abundant in wet depressions (old taro pits?) where not too shaded, dominant in such places in full sun. Coarse, harsh, stiff grass-like sedge with tall, arching, loose sprays of scaly brown flowers and tiny nut-like fruits.

*Cyperus kyllingia Endl.

Rimatuu I., Fosberg 54607

Scattered tufts around abandoned village site; seen at this locality only. Small tufted grass-like sedge, with small, white, globose clusters of tiny flowers.

*Cyperus polystachyos Rottb.

Rimatuu I., Raynal 18030 (P)

Slender wiry slightly tufted sedge, with compact head of narrow green spikelets and three or four long narrow bracts.

*Eleocharis geniculata (L.) R. & S. Spike-rush

Onetahi I., Fosberg & Sachet 54645; Raynal 18016 (P).
Rimatuu I., Fosberg 63772
Honuea I., sight record by Fosberg & Sachet in 1982.

Seen around a small active taro pit near the end of the runway close to the lagoon beach on Onetahi. Perhaps a recent introduction, brought with taro plants by a laborer. Tufts of very slender leaf-like stems 10 cm or so tall, each bearing a tiny scaly pine-cone-like flower spike at the top. Found also to form a belt around the large Cladium marsh on Rimatuu.

Fimbristylis cymosa R. Br.

Onetahi I., Fosberg & Sachet 54635, Sachet 1693a
Tiaraunu I., Fosberg & Sachet 54660
Rimatuu I., Quayle 195 (BKL)

General in openings, forming small tufts, roots fragrant; leaves linear, blunt, slightly stiffish; small button-like tufts of small scaly flowers.

ARACEAE (Arum family)

*Colocasia esculenta (L.) Schott Taro

Onetahi I., Fosberg & Sachet 54644

Planted in mud in a small pit. Plant with edible underground tuberous corms, no above-ground stem, erect purple leaf-stalks bearing large glaucous, arrowhead-shaped, peltate leaves. Seldom flowering. One of the principal Polynesian food plants. Not seen in 1982.

*Cyrtosperma chamissonis (Schott) Merr. Puraka; Giant taro

Reiono I., Sachet & Fosberg 1640

Small patch persisting in ancient taro pit in deep shade. Large tuberous underground corm, with enormous erect leaves, triangular arrowhead-shape, on thick round leaf-stalks to 1.5 m tall, glossy, flower-stalk erect, topped by a folded bract surrounding a spike of crowded very much reduced flowers.

*Syngonium angustatum Schott

Rimatuu I., Fosberg 63777

Large plant, climbing in large tree around ruins of former village.

ARECACEAE (Palm family)

*Cocos nucifera L. Niu; Coconut

Generally planted on all the islands. Tall tree with columnar trunk and enormous pinnate leaves in a giant rosette at top of trunk; flowers, both male and female, borne in large complex branched clusters among the leaves, protected by a woody boat-shaped bract which falls off as the flower cluster expands, flowers cream color, with stiff sepals and petals; fruit a large fibrous drupe with a hard stone 10-20 cm in diameter with one seed completely filling the cavity, shell filled with excellent water when immature, with a layer of white oily flesh when ripe. Had been eliminated from Motu-Aie in 1982.

LILIACEAE

Cordyline fruiticosa (L.) Chev. (cv)

Planted on Onetahi.

TACCACEAE

Tacca leontopetaloides (L.) O. Ktze. Pia; Island Arrowroot

Onetahi I., Sachet 1678; Fosberg & Sachet 54634

Very common in coconut groves. Bearing potato-like underground tubers, no above-ground stem; erect terete leaf-stalks, large palmate, deeply and complexly divided leaves, tall erect hollow flower-stalks with umbellate clusters of small flowers, filiform conspicuous bracts; fruits globose, marble-like, packed with seeds. Tubers an important source of starch for the ancient Polynesians, but bitter and needing processing before use.

ORCHIDACEAE (Orchid family)

Nervilia aragoana Gaud.

Oroatera I., Sachet & Fosberg 1692
Honuea I., Fosberg 54579

Occasional but very local in sandy, usually shaded soil, uncommon. A small ground orchid, with a small fleshy underground corm, a single expanded leaf, and when this disappears a short raceme of whitish delicate flowers appears. Searched for in July 1982 on Honuea but not found.

CASUARINACEAE

Casuarina equisetifolia L. — Toa; Ironwood; She-oak; Beef-wood

Onetahi I., Fosberg & Sachet 54567

Local, probably planted, only seen around camps, but probably native in the Society Islands. A tree with no normal leaves, but with needle-like green jointed branchlets which drop as do leaves; flowers very reduced, in catkin-like clusters; fruits like diminutive pine-cones. Yields a very hard, extremely heavy but brittle timber.

MORACEAE (Mulberry family)

*Artocarpus altilis (Park.) Fosb. — Mai; Breadfruit

Rimatuu I., Fosberg 54601

Planted, only seen at Rimatuu Village. A large tree with milky sap; large alternate deeply cut leaves, flowers very reduced, the male in large club-shaped clusters, the female in light green balls; fruit large, globose or slightly elongate, with geometrically roughened surface. Fruit cooked in various ways and eaten; the staff of life for the ancient Polynesians, still extensively used.

*Ficus carica L. — Edible Fig

Onetahi I., seen planted around buildings by Sachet in 1982.

URTICACEAE (Nettle family)

Laportea ruderalis (Forst.) Chew

Rimatuu I., Quayle 186 (US, BISH, BKL); Wilder 303 (BISH)
Tahuna-rahi I., Sachet 1646
Onetahi I., Sachet 1653
Tiaraunu I., Raynal 18000 (P)
Reiono I., Sachet 1642

Uncommon but generally distributed, mostly in shaded places. A small succulent-stemmed herb with alternate broadly ovate toothed leaves, flowers very small and inconspicuous in branched clusters, fruit small, grain-like. Seen on Motu-Aie and Tahuna-iti in 1982.

Pipturus argenteus (Forst. f.) Wedd. — Roa

Tiaraunu I., Fosberg & Sachet 54657, 54658

Very local in low places in sparse coconut plantation, seen only on Tiaraunu. Large shrub or very small tree, leaves alternate, broad, toothed; flowers in tiny clusters on a string-like spike; fruit

resembling a very small white strawberry. Inner bark tough, used by ancient Polynesians for cordage and bark cloth.

AMARANTHACEAE (Amaranth family)

Achyranthes velutina H. & A.

Motu-Aie I., Fosberg & Sachet 54627; Fosberg 63759

Very local, only seen on Motu-Aie, in interior openings. An elongate ascending herb with opposite gray-green softly pubescent leaves spikes of scaly flowers and small backward-pointing unpleasantly sharp dry fruits.

NYCTAGINACEAE (Four-o'clock family)

Boerhavia tetrandra Forst.

Tahuna-rahi I., Sachet 1648
Motu-Aie I., Fosberg & Sachet 54624; Fosberg 63757
Rimatuu I., Fosberg 63764
Tiaraunu I., Raynal 17999 (P)

Very common, especially in openings and sparse places in coconut groves, where abundant forming a mat on the ground. Prostrate elongate creeping stems from a thick root crown; opposite oblong-elliptic leaves pale beneath; small clusters of tiny pink flowers; sticky, ribbed club-shaped tiny fruits that stick to clothing. Often affected by a white rust fungus, Albugo platensis that causes branches to become erect, condensed, distorted, and witches-broom-like (Fosberg & Sachet 54625).

Pisonia grandis R. Br.

Tahuna-rahi I., Sachet 1647
Motu-Aie I., Fosberg 63760, 63761, 63732; Raynal 18031 (P)
Hiraanae I., sight record by Sachet in 1974.

Common, locally forming groves and forests, but these mostly cleared away when coconuts were planted. Large trees with pale creamy-gray trunks, soft brittle wood; large, usually smooth, opposite, broadly elliptic leaves, clusters of small, pale greenish flowers; dry, very sticky, minutely spiny club-shaped fruits, admirably adapted to be carried sticking to birds' feathers.

PORTULACACEAE (Purslane family)

Portulaca johnii v. Poelln. Purslane

Onetahi I., Fosberg & Sachet 54631; Fosberg 63789
Honuea I., Fosberg 63780

Hiraanae I., Fosberg & Sachet 54653
Rimatuu I., Wilder 949 (BISH)

Very common in openings and edges of woods. Very fleshy small herb with obovate leaves; flowers yellow, rather small, opening late in morning, closing in late afternoon; seeds tiny, black, shiny, borne in small capsules with lids.

LAURACEAE (Laurel family)

Cassytha filiformis L. Giant Dodder

Onetahi I., Sachet 1675, 2548
Rimatuu I., Wilder 305A (BISH); Quayle 188 (BISH)

Very common, especially in open or bushy areas, parasitic on other plants, especially Suriana, often killing it. Leafless, tangled string-like, rootless plant, orange to greenish, twining around other plants, penetrating them with tiny sucker-like haustoria to get nourishment; flowers very small, white, fruit globose, small, white, fleshy.

HERNANDIACEAE

Hernandia sonora L.

Onetahi I., Fosberg & Sachet 54639
Rimatuu I., Fosberg 54583
Hiraanae I., sight record by Sachet in 1974.

Very local, forming groves among coconut trees. Trees reaching very large size, leaves alternate large, round, glossy; branched clusters of grayish-white flowers; fruits black nut-like surrounded by a thin inflated fleshy envelope, white, turning pink, or even deep carmine.

BRASSICACEAE (CRUCIFERAE) (Mustard family)

Lepidium bidentatum Mont. Scurvy-grass

Tiaraunu I., Raynal 18003 (P)
Rimatuu I., Fosberg 54582; Quayle 187 (BISH)
Motu-Aie I., Fosberg & Sachet 54626; Fosberg 63758
Hiraanae I., sight record by Sachet in 1974.
Honuea I., sight record by Fosberg in 1982.

Locally common in semi-open places. An herb, sometimes rather woody at base, with alternate usually coarsely toothed leaves, elongating racemes of tiny whitish flowers and small dry elliptic capsules bearing 2 orange seeds each. Said to have been eaten by early sailors to prevent or cure scurvy.

FABACEAE (LEGUMINOSAE) (Bean family)

*Derris malaccensis Prain ?

Reiono I., Sachet 1644

Sterile vine.

Sesbania coccinea (L.f.) Poir. s. l.

Rimatuu I., Quayle 190 (BISH, K)
Motu Tiaraunu, Raynal 18001 (P)

Small tree or shrub with alternate pari pinnately compound leaves and large deep orange and maroon flowers. Not found on this survey.

Sophora tomentosa L.

Hiraanae I., Fosberg & Sachet 54651; Sachet 2105

One small clump seen in coconut grove in interior of islet. Sprawling shrub 1.5-3 m tall; leaves alternate pinnately compound, grayish green; flowers pea-like, yellow, in racemes; fruit a long lumpy pod, each lump containing a seed.

Vigna marina (Burm.) Merr.

Onetahi I., Fosberg & Sachet 54642; Fosberg 63788
Hiraanae I., sight record by Sachet in 1974, 3 m from high-water mark.

Occasional in openings and edges of coconut groves. Creeping herb with alternate trifoliolate, broad obtuse leaves; yellow pea-like flowers on erect stalks; pods small, cylindric. Roots bear nodules containing nitrogen-fixing bacteria.

RUTACEAE (Citrus family)

*Citrus aurantifolia (Christm.) Swingle — Lime, "citron vert"

Rimatuu I., Fosberg 54592

A few small shrubs in Rimatuu Village around abandoned dwellings. Shrub with spines and alternate elliptic slightly toothed leaves, aromatic when broken; fragrant waxy white flowers and greenish sour fruits with glandular aromatic skin. Juice used for drinks, antiscorbutic.

SURIANACEAE

Suriana maritima L.

Tiaraunu I., Raynal 18006 (P)
Onetahi I., Fosberg & Sachet 54636
Honuea I., sight record by Sachet in 1974.
Rimatuu I., Quayle 189 (BISH), Wilder 312 (BISH), sight record by Fosberg in 1982.

The commonest shrub on the island, abundant around edges of woods and coconut groves at top of beaches, also in openings in interior. Shrub branching from base and abundantly so above; leaves alternate, narrow, numerous; flowers rather small, bright yellow; fruits small, dry, grain-like.

EUPHORBIACEAE (Spurge family)

Acalypha amentacea ssp. wilkesiana (M.-A.) Fosberg

Rimatuu I., Fosberg 54599, 54600

Planted in old village. Shrub with alternate variegated bronze-red, broad, toothed leaves, catkins of small reddish or bronze flowers. Widely planted as an ornamental and hedge plant throughout the tropics. The form here has curious circinately curved leaves (f. circinata).

Codiaeum variegatum (L.) Bl. Croton

Rimatuu I.

One large shrub seen by Sachet in 1973.

Euphorbia hirta L.

Onetahi I., Sachet 1654; Florence 3251 (P, US)
Rimatuu I., Raynal 18027 (P)

Very common around camp site. Small arching, milky, hairy herb with opposite, toothed, pointed leaves and dense clusters of tiny white flowers.

*Pedilanthus tithymaloides (L.) Poit. Shoe-flower

Rimatuu I., Fosberg 54591

Sparingly planted in old village. Fleshy, green-stemmed weak shrub, leaves pointed, arranged in 2 ranks, flowers red, slipper-shaped, pointed. Widely planted in the tropics as an ornamental.

*Phyllanthus amarus Schum. & Thonn.

Onetahi I., Sachet 1651; Fosberg 63784
Rimatuu I., Fosberg 54595; Raynal 18023 (P)

Very local around old village and camp site. Erect herb with very small pinnately arranged, two-ranked leaves, tiny yellowish green flowers, and round capsule-like fruits on slender spreading branches.

*Phyllanthus tenellus Roxb.

Onetahi I., Fosberg 63785

Weed in garden.

SAPINDACEAE (Soapberry family)

*Pometia pinnata Forst. Kava

Rimatuu I.

Large tree in old village, seen by Fosberg in 1973 and 1982.

RHAMNACEAE (Buckthorn family)

Colubrina asiatica (L.) Brongn.

Rimatuu I., Fosberg 54608

One small shrub seen near old village. Scrambling shrub with alternately arranged broad, heart-shaped finely toothed leaves, small open clusters of very small greenish-yellow star-shaped flowers; fruit a hard 3-seeded capsule.

TILIACEAE (Linden family)

Triumfetta procumbens Forst. f.

Onetahi I., Sachet 1668
Rimatuu I., Fosberg 54610

Very common, creeping, forming loose mats in coconut groves. Prostrate spreading creeper with hairy stems and variable often lobed leaves, bright yellow flowers, and burr-like globose fruits.

MALVACEAE (Mallow family)

Hibiscus tiliaceus L. Purau

Onetahi I., Sachet 1673, 1693

Very local on lagoon-sides of islets in edges of woods and coconut groves, in places, at least, probably planted. Spreading, often tangled tree, leaves round, usually pale beneath; flowers large, in few-flowered clusters, yellow with maroon center when opening in morning, turning light maroon and falling toward evening; fruit a 5-parted capsule.

*Hibiscus (hort. var.) Red hibiscus

Rimatuu I., Fosberg 54597

Planted around old village. Shrub with toothed ovate-triangular leaves; large bright red flowers. A widely planted tropical ornamental hybrid, propagated only by cuttings.

*Sida fallax Walp. Ilima (Hawaii)

Onetahi I., Sachet 1674
Rimatuu I., Fosberg 54581, 63763; Raynal 18025 (P); Florence 3265 (P, US).

Local in semi-open coconut groves, uncommon except near old village. Small erect shrub, with round, heart-shaped bluntly toothed leaves, round bright orange flowers.

*Sida rhombifolia L.

Rimatuu I., Fosberg 54603

Rare in abandoned village. Ascending herb with longer rhombic-ovate short-petioled leaves with blunt points, long-stalked dull orange flowers.

Thespesia populnea (L.) Sol. ex Correa Miro

Honuea I., Fosberg 54578
Onetahi I., Fosberg & Sachet 54641; Sachet 1671

Found only as seedlings on beaches. Trees not seen on atoll.

STERCULIACEAE

*Waltheria indica L.

Rimatuu I., Fosberg 63776; Raynal 18010 (P)

Two large flourishing colonies around ruins of former village; not noticed in 1973. A suffrutescent herb, spreading, branched, to 1.5 or 2 m long, flowers small, yellow.

CLUSIACEAE (GUTTIFERAE)

*Calophyllum inophyllum L. — Tamanu

Rimatuu I., Fosberg 54584

Planted around old village and camp site. Very large spreading tree, leaves oblong, leathery; flowers white with yellow stamens, borne in clusters among leaves; fruit pendent, globose, 2.5-3.5 cm in diameter. Widely distributed in Pacific, probably both by human agency and naturally by its floating fruits. Timber hard, workable, highly prized; also a superb shade tree.

CARICACEAE (Papaya family)

*Carica papaya L. — Papaya, Pawpaw

Rimatuu I., Fosberg 54590

Sparingly growing in old village, persisting after cultivation. An erect, usually unbranched small tree with a soft trunk and milky sap; large palmate deeply divided round leaves on long stalks forming a huge rosette at top of stem; male flowers cream color, in large open clusters among leaves, female sessile on stem among and just below leaves, larger, often some bisexual flowers mixed in clusters; fruit orange when ripe, fleshy, melon-like, with many black seeds in large central cavity. Widely planted in tropics for its delicious fruits and the proteolytic enzyme produced in its sap. Readily becomes naturalized, but then the fruit is commonly small and of poor flavor.

CUCURBITACEAE

*Citrullus lanatus var. caffrorum (Alef.) Fosberg — Watermelon, pasteque

A large healthy plant, bearing melons, seen and photographed, near houses back of channel beach, by Sachet in 1974, Onetahi I.

*Cucumis melo L. var. melo — Melon, cantaloupe

A healthy plant with an immature melon, seen and photographed, in garden and climbing on house, near channel, by Sachet in 1974, Onetahi I.

LYTHRACEAE (Loosestrife family)

Pemphis acidula Forst.

Honuea I., Fosberg 54573
Rimatuu I., Fosberg 54604

Reef rock remnant between Honuea and Tiaraunu, Fosberg & Sachet 54613
Tiaraunu I., Fosberg & Sachet 54659
Oroatera I., Fosberg & Sachet 54620
Hiraanae I., sight record by Sachet in 1974.

Locally very common, mostly on rough limestone on seaward coasts and rocks on reef-flat, forming pure stands of low to tall scrub in such places. Much-branched shrub or small tree with very hard dark reddish wood; leaves small, oblong, thick, astringent when chewed; flowers white, rather small; fruit a round somewhat flattened, dark reddish capsule, seeds many, small.

COMBRETACEAE

*Terminalia catappa L. — Indian Almond; Tropical Almond

Onetahi I., Sachet 1669, 1681

A few small trees around camp site. A pagoda-form tree with flattish horizontal branches, large obovate leaves that turn red when old, slender spikes of small white flowers, somewhat flattened ovoid corky fruits with 2 keels, and edible almond-like seeds. Widely planted in the tropics, doubtfully native in eastern Polynesia.

Terminalia glabrata Forst. f. ?

Rimatuu I., Fosberg 63767

A single seedling that must be this, found in interior of coconut plantation.

Terminalia samoensis Rech.

Onetahi I., Fosberg & Sachet 54632

Single tree seen, around camp site. Small tree, with obovate leathery leaves, slender spikes of whitish flowers, small, dark red somewhat elongate cherry-like fruits, said to be edible, at least the almond.

LECYTHIDACEAE

Barringtonia asiatica (L.) Kurz

Hiraanae I.

A sprouted seedling 7 dm tall seen about 3 m back of high-water mark by Sachet in 1974.

ARALIACEAE (Ginseng family)

*Polyscias guilfoylei (Bull) Bailey — Hedge-panax

Rimatuu I., Fosberg 54588; Raynal 18029 (P)

Several plants in old village. Shrub, here reaching small tree-size, very erect, sparingly branched, leaves pinnately compound, leaflets elliptic, coarsely toothed, margins whitish, with an oily smell when broken, strong coumarin odor when dried; flowers in large, loose clusters, small, greenish, very seldom produced; fruits small, somewhat fleshy, rarely seen. Widely planted tropical ornamental.

SAPOTACEAE

*Chrysophyllum cainito L. — Star-apple

Rimatuu I., Fosberg 54589

One small plant seen in old village. Tree with elliptic leaves bright coppery pubescent beneath; fruit globose, edible.

APOCYNACEAE

*Catharanthus roseus (L.) G. Don — Madagascar Periwinkle
Pervenche

Onetahi I., sight record by Sachet in 1974-75.

Seen established around camp site. Erect leafy-stemmed herb, with white or pink flowers, sometimes with dark red eye.

*Plumeria rubra L. — Frangipani

Rimatuu I.
Onetahi I.

Seen planted around old village; also around camp site. Small tree with very thick branches; vari-colored, extremely fragrant five-parted large flowers, much used for garlands.

CONVOLVULACEAE (Morning-glory family)

Ipomoea littoralis Bl.

Onetahi I., Fosberg 63791
Rimatuu I., Fosberg 63766

A purple-flowered morning glory found near the air strip, and a somewhat doubtfully identified sterile vine seen rarely in the undergrowth in the coconut plantation on Rimatuu.

Ipomoea macrantha R. & S. — Pohue; Wild Moon-flower

Rimatuu I., Wilder 306 (BISH)
Honuea I., Fosberg 54576, Sachet 2647 (seedling)
Onetahi I., Fosberg & Sachet 54640, 54661
Tiaraunu I., Raynal 18005 (P)

Occasional to common in scrub and undergrowth near the seaward coasts and in interiors of islets. Extensive twining liana becoming woody in older parts, leaves heart-shaped, flowers large, trumpet-shaped, white, opening at night, collapsing in afternoon or when exposed to strong sun, fruit a globose capsule enclosed in fleshy enlarged sepals, then drying to a parchment-like texture.

BORAGINACEAE (Borage family)

Cordia subcordata Lam. — Tou

Rimatuu I., Quayle 185 (BISH, US); Florence 3263 (P, US)
Honuea I., Fosberg 54577
Onetahi I., Fosberg & Sachet 54643; Sachet 1670
Tahuna-rahi I., Sachet 1649
Hiraanae I., Raynal 18017 (P)

Occasional in margins of woods and coconut plantations, especially near beaches. Tangled tree with low branches, leaves alternate, with broad ovate or elliptic, slightly rough, blades and often yellow stalks; flowers in small clusters, large, brilliant deep orange, corolla thin, delicate, fruit nut-like, enclosed in enlarged calyx. Wood hard but workable, prized for carving, banded light and dark brown.

Heliotropium anomalum H. & A.

Rimatuu I., Wilder 951 (BISH)

Dwarf shrub with narrow silky leaves, dense clusters of fragrant white flowers with yellow centers. Not found on present survey.

Tournefortia argentea L. f. — Tree Heliotrope

Rimatuu I., Fosberg 54612; Quayle 191 (BISH, NY)
Onetahi I., Fosberg & Sachet 54668
Tiaraunu I., Raynal 18008 (P)

Locally common to rare, along seaward beach ridges, in places dominating marginal vegetation, old trees persisting in interior but not reproducing. Shrubs and small trees, leaves obovate, spirally arranged, fleshy, gray-green, silky, flowers small, white, fragrant, in clusters with "scorpioid" or fiddle-neck shaped branches fruit a pea-like pale green drupe with four small stones, this drying to a small corky globose floating dry fruit.

SOLANACEAE

*Solanum lycopersicum L.

Onetahi I.

Seen by Sachet in 1974-75, growing around houses, fruiting.

BIGNONIACEAE

*Saritea magnifica (Sprague ex v. Steenis) Dugand

Onetahi I., Fosberg 63783

Sterile vine planted in garden near buildings.

RUBIACEAE (Coffee family)

*Gardenia taitensis DC. Tiare Tahiti; Tahitian Gardenia

Rimatuu I., Fosberg 54598; Quayle 184 (BISH); Raynal 18028 (P)
Oroatera I., Sachet & Fosberg 1683

Planted around old village and camps, a few large old plants persisting in forest. Shrub or small tree, leaves opposite, broad, obovate; flowers solitary among leaves, large, white, very fragrant, corolla lobes 6-7, spreading. Generally planted in Polynesia for its highly prized deliciously fragrant flowers.

Guettarda speciosa L.

Rimatuu I., Quayle 192 (K, BISH)
Honuea I., Fosberg 54572
Onetahi I., Fosberg & Sachet 54638, 54662, 54663, 54664, 54665, 54666, 54667; Sachet 1655
Hiraanae I., Fosberg & Sachet 54652

Very common generally. Shrub or small to medium-sized tree, with large, broad, obtuse leaves, conspicuous stipules; small clusters of large white flowers, opening and very fragrant at night, losing their fragrance and dropping their corollas during following day; fruit a globose white fleshy-fibrous floating drupe.

Hedyotis romanzoffiensis (C. & S.) Fosb.

Honuea I., Fosberg 54574, 63778

Scattered in open scrub vegetation on coral sand and gravel, seen only on Honuea Islet. Small shrub with opposite, obovate, small leathery leaves; greenish-white flowers in very few-flowered

clusters; fruit globose, fleshy, white to purple, opening at one end to let out the small seeds.

Morinda citrifolia L. Nono

Onetahi I., Fosberg & Sachet 54629

Common generally in coconut groves. Shrub or small tree, with opposite, large, elliptic, glossy leaves; small heads of small white flowers, fused together at base; fruit dull whitish, potato-shaped, fleshy, with many large seeds, developing a rancid very disagreeable odor when old.

Timonius polygamus (Forst.) Rob.

Rimatuu I., Quayle 193 (BISH, US, P)
Honuea I., Fosberg 54569, 54570, 54571
Tiaraunu I., Fosberg & Sachet 54614, 54655, 54656
Onetahi I., Raynal 18013 (P); seen by Sachet in 1982
Reiono I., Sachet 1639

Very common generally in undergrowth and in open scrub. Shrub with opposite obovate leaves, very variable in shape; small white flowers, male in few-flowered clusters, female solitary; fruit black, fleshy, globose, with a number of small stones.

CAMPANULACEAE (Bluebell family)

*Hippobroma longiflora (L.) Don Star-of-Bethlehem

Onetahi I., Sachet 1652; Raynal 18012 (P)

Established around camp site. Small herb with milky sap; alternate, long, pointed, coarsely toothed leaves; long-tubular, white, showy, star-shaped flowers, capsular fruits with many small seeds. Said to be very poisonous.

GOODENIACEAE

Scaevola sericea Vahl var. sericea Naupata

Onetahi I., Fosberg & Sachet 54637

Very common especially around peripheries of islets and in marginal fringe vegetation. Low rounded shrub with rosettes of leaves at ends of branchlets, obovate, bright green; flowers in small clusters among leaves, white, corolla 5-lobed, one-sided as though half had been torn away; fruit globose, fleshy, white, or purple on one side, with a large slightly ribbed stone.

Scaevola sericea var. tuamotuensis (St. John) Fosberg

Rimatuu I., Fosberg 63770

Rare, only one patch seen at the top of the beach near the ruins of the former village. It differs from var. sericea in the rather depressed habit, usually narrower, glabrous leaves and in the dull purplish yellow flowers.

COMPOSITAE (ASTERACEAE) Aster family

*Bidens pilosa L. var. pilosa

Onetahi I., Fosberg 63792

Common near air strip. Differs from var. minor in lacking ray flowers.

*Bidens pilosa var. minor (Bl.) Sherff

Rimatuu I., Fosberg 54585, 63768; Raynal 18026 (P)
Onetahi I., Florence 3256 (P, US)

Abundantly naturalized in old village. Weedy herb, leaves opposite, pinnately 3-5 foliolate, leaflets pointed and finely toothed; flowers small, yellow, in dense heads, marginal corollas somewhat expanded, petaloid, white; fruit black, needle-shaped, with 2 or 3 barbed, stiff, sharp, short bristles at one end.

*Conyza bonariensis (L.) Cronq. Large Horse-weed

Rimatuu I., Fosberg 54587, 63775; Raynal 18020 (P, US)

Occasional in old village. Tall herb with unbranched leafy stem with narrowly oblong, scattered, coarsely toothed leaves, much branched conical inflorescence at top, flower heads small, of many closely packed very tiny flowers; fruiting heads masses of brownish white fine bristles on tiny dry prismatic fruits, tufts of bristles acting as parachutes to carry fruits on wind.

*Emilia fosbergii Nicolson Flora's paint-brush

Onetahi I., Fosberg 63786

Soft-stemmed slightly glaucous weed with red flower-heads, in gardens around buildings, doubtless a recent introduction.

*Vernonia cinerea (L.) Less. Little Iron-weed

Rimatuu I., Fosberg 54586; Raynal 18021 (P); Florence 3260 (P, US)

Common in old village. Small herb with leafy stems and open terminal clusters of narrow purplish flower heads; these showing fine white bristles when past flowering and in fruit.

*Wedelia trilobata (L.) Hitchcock

Onetahi I., very abundant near buildings, seen by Sachet in 1982.

APPENDIX II

Table of occurrence of indigenous and long-established exotic plants in Tetiaroa by islets.

Symbols used in Table

a	abundant
la	locally abundant
c	common
lc	locally common
l	local
o	occasional
r	rare
s	seedlings only
l(cu)	locally cultivated

HERBS, VINES and CREEPERS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Achyranthes velutina								1					
Asplenium nidus	1(cu)		1c	a	1a	1a	a			1		1(cu)	
Boerhavia tetrandra	c	r	c	a	1	1a	c	a	c		a	o	
Cassytha filiformis	a	a	c	r		c	a		1a	1a	1	1	
Cenchrus echinatus	1											1	
Cenchrus echinatus var. hillebrandii	1											1	
Cladium jamaicense	1	1a	a			1	1a					1a	
Cynodon dactylon	1												
Cyrtosperma chamissonis										1			

HERBS, VINES and CREEPERS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Davallia solida	r		r	r		la	la					1 (cu)	
Derris malaccensis										o			
Digitaria radicosa												1	
Digitaria setigera												1	
Digitaria stenotaphrodes			1								1		
Elaeocharis geniculata	1	1										la	
Emilia fosbergii	1												
Eragrostis tenella	la	1										1	
Euphorbia hirta	la											la	

HERBS, VINES and CREEPERS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Fimbristylis cymosa	c	l	c			l	lc					c	
Hippobroma longiflora	l												
Ipomoea littoralis	l											l	
Ipomoea macrantha	c	s	c			c	c	lc		o		r	
Laportea ruderalis	l	l	l		r	r	o	o	o	r	l	o	
Lepidium bidentatum	r	l	c	r		l	l	la				l	
Lepturus repens	a	c	a	la	l	c	c	c	c	c	c	a	
Nephrolepis hirsutula	l		lc			la	lc						
Nervilia aragoana		r					o						

HERBS, VINES and CREEPERS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Polypodium scolopendria	a	la	a	a	a	a	c-a	c	l	c	c	c	
Portulaca johnii	a	o	o	a	o	l	o	c	c	c	c	o	
Psilotum nudum	r		o			o	o			r		r	
Sida rhombifolia L.												l	
Tacca leontopetaloides	a	l	c	la		a	a					a	
Thuarea involuta			o		l	r	l			a			
Triumfetta procumbens	la	l	a	c		c	c	r		l		a	
Vigna marina	l					l							
Waltheria indica												l	

SHRUBS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Hedyotis romanzoffiensis		lc											
Pemphis acidula		lc	r		c	la	la	la			lc	r	a
Scaevola sericea	la	c	c	o		r	a			la	lc	la	
Sesbania coccinea			r									r	
Sida fallax	l											l	
Sophora tomentosa						r							
Suriana maritima	a	a	c	a	l	l	a		la		c	la	
Timonius polygama	a	c	lc	o	r		o			l			
Colubrina asiatica												r	

TREES and LARGE SHRUBS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Calophyllum inophyllum	1											1a	
Carica papaya												o	
Casuarina equisetifolia	1c		c										
Cocos nucifera	a	a	a	a	c	a	a	o	1	a	a	a	
Cordia subcordata	1	s	r			1		1	1c	1a	r	1a	
Gardenia taitensis	1						r					1	
Guettarda speciosa	a	c	a	c	c	c-a	o	o		1	c	c	
Hernandia sonora	1		o			1						1	
Hibiscus tiliaceus	1c		o			1	1					1a	

TREES and LARGE SHRUBS	Onetahi	Honuea	Tiaraunu	Motu-tauini	Motu-auroa	Hiraanae	Oroatera	Motu-Aie	Tahuna-rahi	Reiono	Tahuna-iti	Rimatuu	rock
Morinda citrifolia	c		c	l		c-la	c			o		c	
Pandanus tectorius	c	a	c	o	o	l	c	l	c	la	l	la	
Pipturus argenteus			l										
Pisonia grandis		r	c	c	a	c	o	a	a	a	c	r	
Terminalia catappa	l											l	
Terminalia samoensis	r												
Thespesia populnea	s	s											
Tournefortia argentea	lc	c	c	a	a	la	c	c	a	c	a	lc	

APPENDIX III

List of established planted species at Rimatuu village and around camp-sites on Onetahi and Tiaraunu islets (1973).

Acalypha amentacea ssp. wilkesiana
Artocarpus altilis
Calophyllum inophyllum
Carica papaya
Casuarina equisetifolia
Catharanthus roseus
Chrysophyllum cainito
Citrus aurantifolia
Cocos nucifera
Codiaeum variegatum
Cordia subcordata (probably indigenous)
Cordyline fruticosa cv.
Crinum sp.
Gardenia taitensis
Hibiscus (hort. var., red)
Hibiscus tiliaceus (possibly indigenous)
Pedilanthus tithymaloides
Plumeria rubra
Polyscias guilfoylei
Pometia pinnata
Syngonium angustatum
Terminalia catappa
Terminalia samoensis (possibly indigenous
Wedelia trilobata

APPENDIX IV

List of recently planted ornamentals and useful plants (1973, 1974, 1975)

Acalypha hispida
Allamanda hendersonii
Allamanda sp.
Annona reticulata
Apium graveolens
Asclepias curassavica
Alternanthera
Bougainvillea sp.
Catharanthus roseus
Citrullus lanatus
Citrus nobilis
Cucumis melo
Dracaena or Cordyline sp.
Eichhornia crassipes
Hippeastrum sp.
Leucaena leucocephala
Muntingia calabura
Ocimum sp.
Persea americana
Plectranthus scutellarioides
Polyscias fruticosa
Portulaca grandiflora
Saritaea magnifica
Solanum melongena
Spondias dulcis
Syngonium angustatum
Thevetia peruviana

In addition there is the following list, furnished in 1973 by Miss Michèle Darr, of plants said to have been recently brought to Tetiaroa. This is copied exactly except for correction of some obvious spelling errors. The numbers apparently indicate the numbers of cuttings or rooted plants introduced. Possible identifications are given in [ ].

110	Tiare Tahiti [Gardenia taitensis]
3	Tiare Moorea [Tabernaemontana divaricata]
20	Taina [Gardenia jasminoides]
80	Tipanier (Bouture) [cuttings of Plumeria]
3	Pedilanthus [P. tithymaloides]
10	Laurier Rose [Nerium]
1	Pittosporum
10	Thevetia [T. peruviana]
25	Pandanus Panache
25	Plumbago Route [Plumbago indica]
30	Pervenches [Catharanthus roseus]

50 Pourpier [Portulaca grandiflora]
50 Cosmos [Bidens sp.]
20 Gomphrena [G. globosa]
40 Rhoeo [R. spathacea]
5 Lantana Mauve [L. montevidensis]
10 Asparagus [A. sp.]
4 Sansevieria [S. trifasciata ?]
20 Gros Poireau Jaune [?]
Amaryllis [Hippeastrum sp. ?]
Crinum Jaune [?]
10 Strobilanthus à Feuille Rouge [Pseuderanthemum ? or Graptophyllum ?]
10 Crotons [Codiaeum variegatum]
10 Begonias [B. sp.]
10 Impatiens [I. sultanii? or I. balsamina ?]
20 Amaryllis [Hippeastrum sp. ?]
1 Sac [bag] Wedelia [W. trilobata]
100 Boutures [cuttings] Hibiscus [H. sp. ?]
1 Sac [bag] Pothos [Rhaphidophora aurea ?]

Additional planted species seen in 1982 on Onetahi:

Acalypha amentacea ssp. wilkesiana
Alternanthera brasiliana
Alocasia macrorrhiza
Asplenium nidus
Begonia sp.
Codiaeum variegatum
Carica papaya
Casuarina equisetifolia
Cordyline fruticosa
Crinum asiaticum
Cryptostegia grandiflora
Dieffenbachia seguine
Ficus carica
Impatiens sultanii
Ipomoea batatas
Pilea microphylla
Sanseviera trifasciata
Saritaea magnifica
Wedelia trilobata
Zebrina pendula

APPENDIX V: List of "weedy" species

These are introduced plants that behave in a somewhat aggressive manner, especially in disturbed or pioneer situations. Some are potential pests.

Bidens pilosa
Cenchrus echinatus
Conyza bonariensis
Cynodon dactylon
Cyperus kyllingia
Cyperus polystachyos
Digitaria radicosa
Digitaria setigera
Eleusine indica
Emilia fosbergii
Eragrostis tenella
Euphorbia hirta
Hippobroma longiflora
Ipomoea littoralis
Phyllanthus amarus
Sporobolus fertilis
Vernonia cinerea
Wedelia trilobata

APPENDIX VI

List of animals collected for which we have identifications

Coenobita perlatus Milne Edw. - Red hermit crab
Coenobita brevimanus Dana - Purple hermit crab
Cardiosoma carnifex (Herbst) - Land crab

All determined by Dr. Dennis Devaney

Birgus latro - Coconut crab

Aedes (Stegomyia) polynesiensis Marks - Day-flying mosquito

Determined by W. A. Steffan

Spodoptera mauritia (Boisduval) - Cut-worm

Determined by D. M. Weisman

Emoia cyanura (Less.) - Blue-tailed Skink
Gehyra oceanica (Less.) - Gecko

Both determined by George Zug

Scolopendra morsitans - Centipede, cent pied

Fig. 1 Landing strip on Onetahi Islet, coconut plantation in background. FRF, 1973

Fig. 2 Narrow pass (hoa) between Hiraanae and Oroatera Islets, N side of atoll; boobies flying overhead. MHS, 1974-75

Fig. 3 Seaward end of hoa between Hiraanae and Oroatera with Pemphis and Tournefortia. MHS,1974-75

Fig. 4 Wind-sheared Tournefortia-Scaevola scrub on Motu-Aie. MHS,1974-75

Fig. 5 Lagoon shore on N side, coconut plantation. FRF,1973

Fig 6 Seaward shore, coconut plantation with protective native scrub fringe. FRF, 1973

Fig. 7 Coconut palms with Pemphis acidula scrub red-footed boobies, adult and young on nest. MHS, 1974-75

Fig. 8 Reiko Sato looking at red-footed booby on nest in Pemphis forest, Motu-Aie. MHS, 1974-75

Fig. 9 Red-footed booby in Tournefortia tree. FRF, 1973

Fig. 10 Red-footed booby fledgling on nest, in Pemphis tree. MHS, 1974-75

Fig. 11 Red-footed booby downy young on nest in Pemphis bush. MHS, 1974-75

Fig. 12 MHS looking at young red-footed booby on nest in Pemphis forest. FRF, 1973

Fig. 13 Tahuna-iti Islet, beach fringe of Tournefortia argentea in front of coconut grove, blue-faced boobies on ground at top of beach. FRF, 1982

Fig. 14 Tahuna-iti, Tournefortia with Suriana maritima in background. FRF, 1982

Fig. 15 Onetahi Islet, ocean beach. Tournefortia in flower, Suriana maritima covered with strings of Cassytha filiformis. MHS, 1973

Fig. 16 North side of atoll, erosion remnants of higher reef rock, with Pemphis acidula and nesting birds. MHS, 1973

Figs. 17 and 18 N side of inner part of passage between Tiaraunu and Honuea islets, showing conglomerate platform with intertidal notch or undercut and Pemphis acidula on bare rock. MHS, 1973

Fig. 19 Rimatuu Islet, Pandanus tree at back of seaward beach. FRF, 1982

Fig. 20 Rimatuu Islet, head of Pandanus tectorius fruits. FRF, 1982

Fig. 21 Rimatuu Islet, coconut plantation choked with seedlings from fallen nuts. FRF, 1982

Fig. 22 Honuea Islet, fruiting Timonius polygamus. FRF, 1982

Fig. 23 Honuea Islet, staminate flowering Timonius polygamus. FRF, 1982

Fig. 24 Honuea Islet, fruiting Hedyotis romanzoffiensis. FRF, 1982

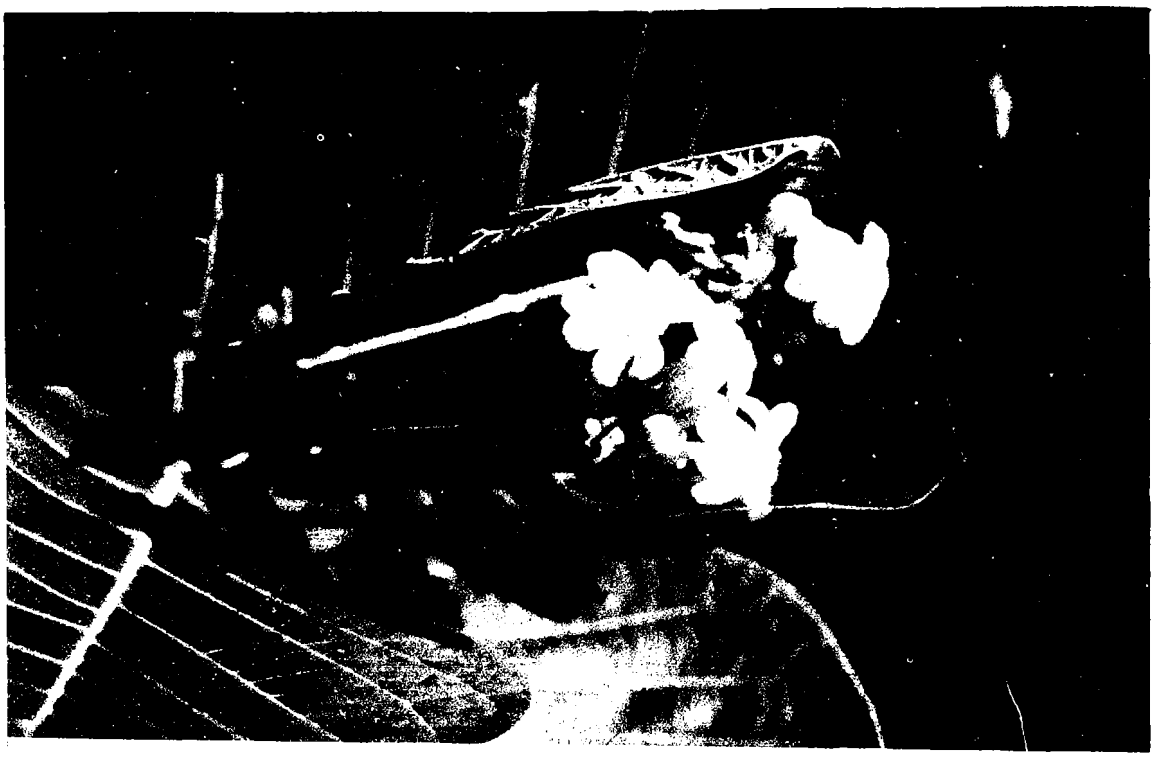

Fig. 25 Honuea Islet, flowering Guettarda speciosa. FRF, 1982

Fig. 26 Honuea Islet, fruiting Guettarda speciosa. FRF, 1982

Fig. 27 Motu Aie, staminate infloresence of Pisonia grandis. FRF, 1982

Fig. 28 Motu Aie, staminate and pistillate flowers and fruit on same tree of Pisonia grandis. FRF, 1982

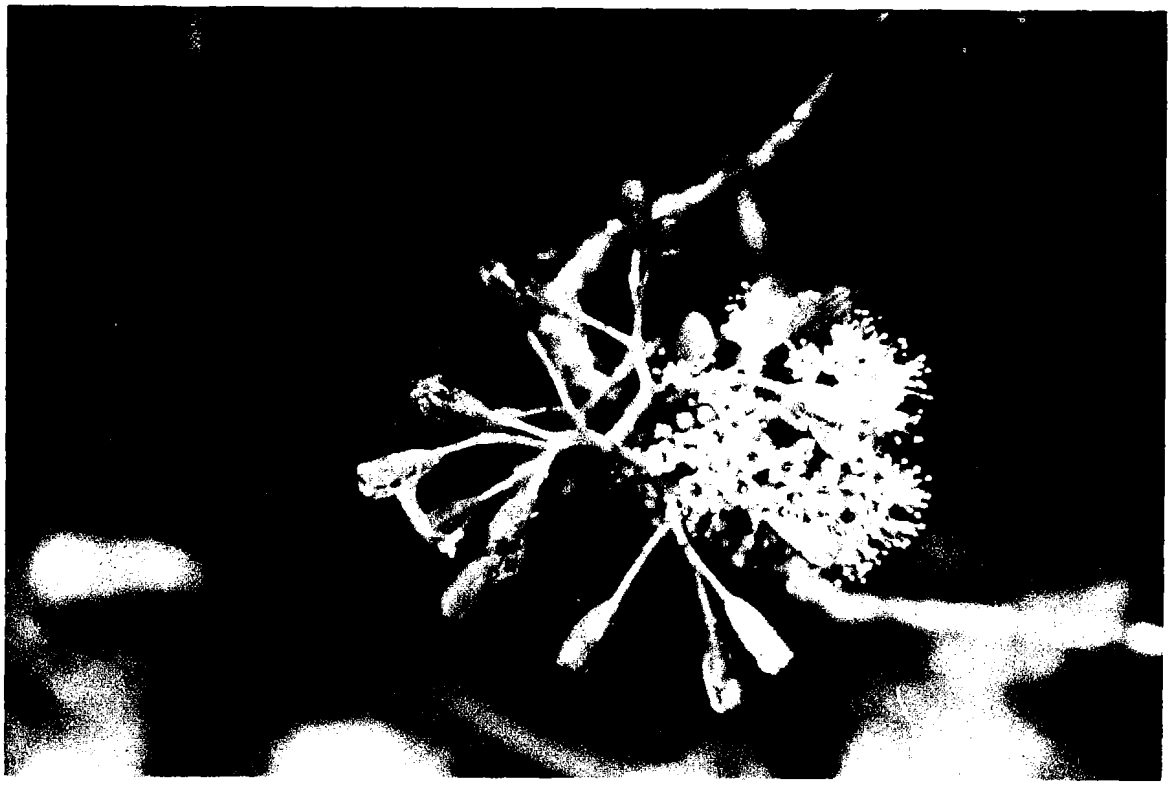

Fig. 29 Tiaraunu Islet, Casuarina trees in sedge marsh. MHS, 1973

Fig. 30 Onetahi Islet. Hernandia grove at W end of airstrip, with remnants of limestone marae slabls. MHS, 1973

Figs. 31 and 32 Onetahi Islet, along airstrip. Ruins of ancient marae excavated by Y. Sinoto. MHS, 1973

Fig. 33 Onetahi Islet, partially restored marae in coconut plantation, near airstrip. MHS, 1983

Fig. 34 Onetahi Islet, basalt round cobbles brought from Tahiti by aboriginal inhabitants for use in cooking oven. MHS, 1973

Fig. 35 Rimatuu Islet, Eleocharis geniculata zone in front of Cladium jamaicense, coconut plantation in background. FRF, 1982

Fig. 36 Tahuna-iti Islet, results of 1983 hurricane, note turned up coconut root-masses. Tahuna-rahi and Reiono Islets in distance. MHS, 1983

Fig. 37 Onetahi Islet, badly eroded beach front along passage; buildings were in use. MHS, 1982

Fig. 38 Same place, beach completely eroded away by 1983 hurricane exposing tree roots; buildings destroyed. MHS, 1983

Fig. 39 Onetahi Islet, beach along pass washed away by 1983 hurricane. MHS, 1983

Fig. 40 Tahuna-iti Islet, trees defoliated in interior of islet by 1983 hurricane. MHS, 1983

Fig. 41 Tahuna-iti, destruction of vegetation by 1983 hurricane. Compare with Figs. 13 and 14. MHS, 1983

Fig. 42 Tahuna-iti, defoliation of trees where frigate birds and boobies roost. Many dead birds were found under the trees. MHS, 1983