Dynamics of Some Pacific Island Forest Communities in Relation to the Survival of the Endemic Flora[1]

by W. STRAATMANS

Introduction

Efficiency of dispersal and adaptability have been described by Ridley (1) as the two factors which determine the survival of a species.

Guppy (2) has shown that longevity of seeds combined with buoyancy in seawater is responsible for the wide distribution of a large group of species on the coasts of all Pacific islands. The presence of this coastal flora partly accounts for the remarkable sameness in the vegetation of low coral islands and atolls throughout the entire Pacific region.

The elevated islands, however, often provide special ecological niches for endemic and rare flora. The island of 'Eua in the Tonga Group is an example.

Because of its topography—classically described by Hoffmeister (3)—'Eua Island is particularly suitable for an investigation of the factors which determine the survival of endemics on a Pacific island. Low coasts and sandy beaches are so scarce that only one hazardous landing place allows entry of small craft. Eastern cliffs, facing the prevailing winds, are sheer and rugged. A secluded central depression is surrounded by high ridges which merge towards the south in a broad high plateau. The Central Valley drains through a creek which reaches the sea through a gap in the encircling ridge. The Central Valley particularly is the home of many endemics. Practically the whole island is covered by primary forest.

Between the years 1951 and 1953 the author studied the vegetation dynamics in the major forest communities of this island. Some of the results of these studies are reviewed here in relation to the survival of the endemic species as described by Yuncker (7).

The Vegetation Communities

On this small Pacific island of 34 square miles the vegetation communities are rather difficult to recognize. As Hürlimann (4) has shown there is considerable overlap between them and moreover, the variation on sea-facing and land-facing slopes provides an intricate and variable mosaic. For the purpose of this study six vegetation communities are described.

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I. The *Alphitonia-Rhus* association of the south-western ridges and slopes consists of well-developed stands of *Rhus taitensis* (Anacardiaceae) and *Alphitonia zizyphoides* (Rhamnaceae) with *Elattostachys falcata* (Urticaceae) as a minor component. The association occurs as an open primary forest where light penetrates rather freely to the forest floor. *Alphitonia zizyphoides* occurs more frequently on the sea-facing slopes, mixed with *Pleiogynium solanderi* (*Anacardiaceae*) and *Polyscias multijuga* (Araliaceae). *Rhus taitensis* prefers the land-facing slopes where it occurs mixed with *Canarium harveyi* (Burseraceae), *Dysoxylum tongense* (Meliaceae), *Glochidion concolor* (Euphorbiaceae), *Tarenna sambucina, Litsea mellifera* (Lauraceae) and *Bischofia javanica* (Euphorbiaceae) (Figures 1 and 4).

II. The *Calophyllum-Elattostachys* association, which is typical of the south-eastern ridges and terraces of 'Eua, is a dark shady primary forest with quite a variety of species. *Calophyllum vitiense* (Guttiferae) and *Elattostachys falcata* are dominant. Towards the south and south-west *Elattostachys falcata*

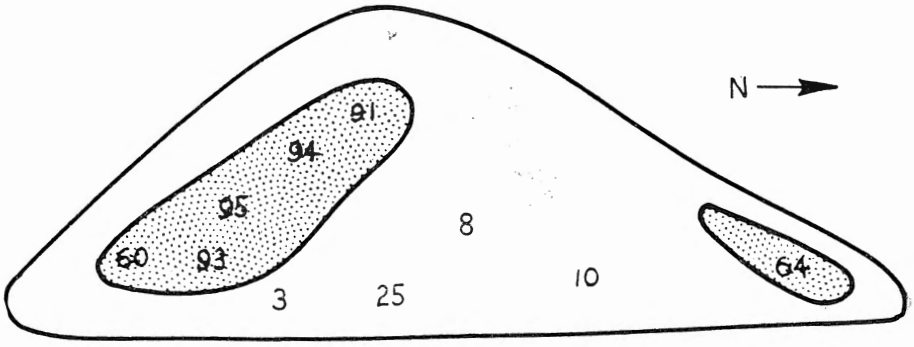

Figure 1. Total frequency of *Alphitonia* and *Rhus* per hundred trees in ten forest plots on different parts of 'Eua island. The largest area of the *Alphitonia-Rhus* association (hatched) is situated on the south-western part of the island.

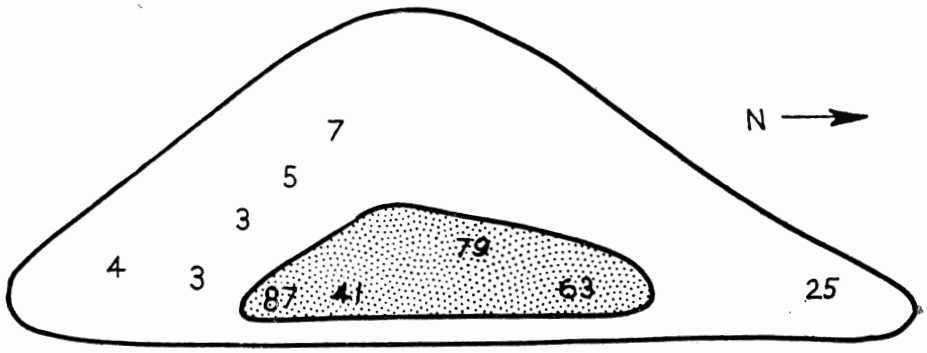

Figure 2. Total frequency of *Calophyllum, Elattostachys* and *Disoxylon* per hundred trees in ten forest plots on 'Eua (same as in figure 1). The largest area of the *Calophyllum-Elattostachys* association (hatched) is situated on the eastern side of the island.

merges into the *Alphitonia-Rhus* association mixed with *Dysoxylum forsteri* on the seaward side and *Cryptocarya hornei* (Lauraceae) on the landward side. Sea-facing sections of the *Calophyllum-Elattostachys* association, particularly on the eastern side of the island, are extremely steep and rugged with rocks and pinnacles protruding through the forest floor. *Calophyllum inophyllum* is here very frequent and often replaces *Calophyllum vitiense.* The dominant species occur here mixed with *Diospyros ferrea* (Ebenaceae), *Diospyros ellipticifolia* var. *elliptic, Xylosma orbiculatum* (Flacourtiaceae), *Myristica hypargyrea* (Myristicaceae), *Grewia crenata* (Tiliaceae) and the impressive palm *Pritchardia pacifica* (Figures 2 and 4).

Inland, this association merges gradually into the moist forest of the Central Valley. The following species are common associates: *Diospyros samoense, Cryptocarya hornei, Garcinia myrtifolia, Citronella samoensis, Maniltoa amicarum, Elaeocarpus tonganus.*

III. The moist primary forest of the Central Valley consists of a rich combination of species, none of which are conspicuously dominant. *Laportea harveyi* reaches an imposing stature, particularly along the banks of the gully system. Many species previously mentioned occur here casually as impressive specimens in mixed stands of *Ficus scabra* (Moraceae) and *Ficus tinctoria, Meryta macrophylla* (Araliaceae), *Glochidion ramiflorum* and *Syzygium corynocarpum* (Myrtaceae). It is particularly this hygrophilous environment which provides the ideal habitat for several important endemic species.

IV. The grasslands on the western slopes of the eastern ridge form an integral part of the primary vegetation of 'Eua island. Hoffmeister (3) described in 1932 how certain sections were overgrown with *Lantana* and *Indigofera,* to which species *Psidium guajava* may be added. Overgrazing has caused a further deterioration of these grasslands over the last thirty years.

V. The coastal community with *Pandanus tectorius, Hibiscus tiliaceus, Thespesia populnea, Guettarda speciosa, Vitex trifolia, Erythrina variegata, Barringtonia asiatica, Tournefortia argentea, Leucaena leucocephala* and *L. insularum* as typical representatives, is similar to the vegetation described by Guppy as having originated from seaborne buoyant seeds. On 'Eua this vegetation is not as well-developed as on many other islands with extensive low foreshores, tidal flats and beaches; there has been comparatively little influx of floating seeds on the cliffy coasts of 'Eua and the tree vegetation of the primary forest often advances right to the edge of the terraces.

VI. The secondary forest is varied and the species composition depends to a large extent on land use and crop rotation.

Generally speaking, virgin forest is not cleared haphazardly in indigenous farming. Some trees are left standing because they produce fragrant flowers or fibre, oil, spices, dyes or fruit. Also, as Kajewski (5) emphasized, "certain trees or even patches of forest may be tabu". The resulting secondary forest is under

some form of semi-management and since some trees are tabu and others useful the system might be termed "tabu-utilitarian." In addition, several introduced species are planted for particular purposes.

Common secondary forest species and their uses include: *Aleurites moluccana* (oil and dye), *Artocarpus altilis* (fruit), *Bischofia javanica* (dye), *Citrus maxima* (fruit), *Cordyline fruticosa* (fibre), *Ceiba pentandra* (fibre), *Entada phaseoloides* (soap-bark), *Hibiscus tiliaceus* (fibre), *Inocarpus fagiferus* (fruit), *Mangifera indica* (fruit), *Morinda citrifolia* (medicinal), *Pandanus tectorius* (fibre and fruit), *Pometia pinnata* (fruit). Food crops may be grown in clearings or under open secondary forest and a host of weedy species accompanies this man-made environment. Hürlimann (6) has studied these weed communities in relation to land use and crops grown.

Rare and Endemic Species

A review of the rare and endemic species and the extent of their occurrence would have been impossible without the published records of Yuncker (7). The ecological niches of the endemics depend on the equilibrium between the primary forest communities which have been outlined earlier.

Even the open *Alphitonia-Rhus* association harbours some endemics. *Guioa lentiscifolia* (Sapindaceae), a small tree, is often found on western sea-facing slopes where *Alphitonia zizyphoides* occurs most frequently. On the other hand, the tree *Planchonella membranacea* (Sapotaceae) is found both with *Rhus* and with *Alphitonia zizyphoides* on land-facing slopes.

Elattostachys is often accompanied by *Cryptocarya hornei* (Lauraceae), which has already been mentioned previously. This medium sized tree has for some time been regarded as an endemic of Fiji. Apparently its range extends further south to 'Eua island. In the same habitat of semi-shade, the tree *Podocarpus pallidus* (Podocarpaceae) is mostly found on land-facing slopes. This is a new species, a true Tongan endemic. Mention should also be made of *Homalium vitiense* (Flacourtiaceae) formerly regarded as a Fijian endemic once found on 'Eua (1890) but unconfirmed by Yuncker (1959).

In the dense forest of the south-eastern part of the island, i.e. in the margin of the *Calophyllum inophyllum* forest, the shrub *Canthium sessilifolium* (Rubiaceae) is found, which was previously regarded as confined to Fiji. In the same environment the 'Euan endemic shrub *Ixora yunckeri* (Rubiaceae) occurs. Another typical cliff dweller is the endemic shrub *Pittosporum yunckeri* (Pittosporaceae). *Wikstroemia rotundifolia* (Thymelaeceae) is also often found on seaward cliff faces. This is a shrub endemic throughout Tonga. The interesting shrub *Osteomeles anthyllidifolia* (Rosaceae) is found in the same habitat. This species, known in the Tonga group from 'Eua only, is, according to Yuncker, also found in the Ryukyu Islands, Bonin Islands, Hawaiian Islands, Pitcairn and other islands of Polynesia.

Several of the above mentioned species, although well adapted to the semi-xeric or halophytic conditions of the eastern sea-facing cliffs of the island, may also be found under hygrophilous conditions of the Central Valley. However, the deeply shaded forest floor of the Central Valley sustains a most luxuriant and complex vegetation in which tree ferns, lianas and climbers abound. The ferns *Dryopteris euaensis* and *Dryopteris macroptera* (Polypodiaceae) are endemics of 'Eua. The tree fern *Cyathea rugosula* (Cyatheaceae) is also found on other islands of the group. Among the lush growth of ferns and trees there are many fine specimens of another 'Euan endemic, the climber *Freycinetia urvilleana* (Pandanaceae).

Agatea violaris (Violaceae) a plant previously believed to be an endemic

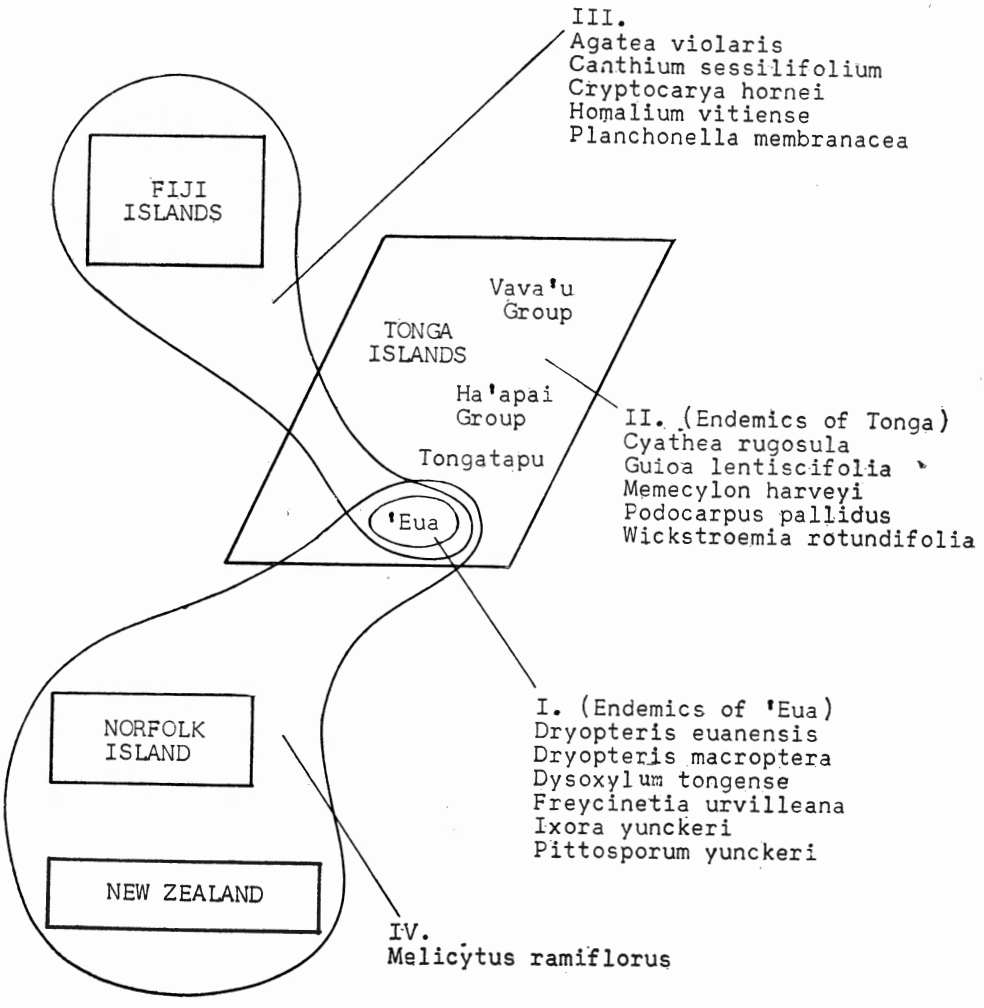

Figure 3. Distributional relationships of some plant species found on 'Eua island.

of Fiji, was also found in these surroundings. Yuncker describes it as a shrublike woody plant. Two more trees should finally be mentioned, i.e. the small tree *Memecylon harveyi* (Melastomataceae) and the impressive tree *Dysoxylum tongense* (Meliaceae), the latter found exclusively on 'Eua.

In Figure 3 the endemic species have been placed in groups indicating the extent of their distribution.

The Dynamics of Forest Communities

Smith (9) has pointed out that there is generally little information on the succession of forest communities, particularly in the interior of forests.

In order to assess the trend of the dynamics in the forest communities as found on 'Eua today, the pattern of seedling establishment for all trees over three feet in girth was recorded in ten observation plots. The probable future species composition may be forecast to some extent from the proportion of the different species in forest regrowth. It was found that the seedling establishment of *Elattostachys* is more abundant in open forest and that of *Calophyllum* more in dense and shady forest. Where a large number of seedlings of *Elattostachys* is established, *Calophyllum* is in the minority. Figure 4 shows this tendency of both associated species to dominate singly in particular areas.

Seedling establishment of *Myristica hypargyrea,* like that of *Calophyllum*

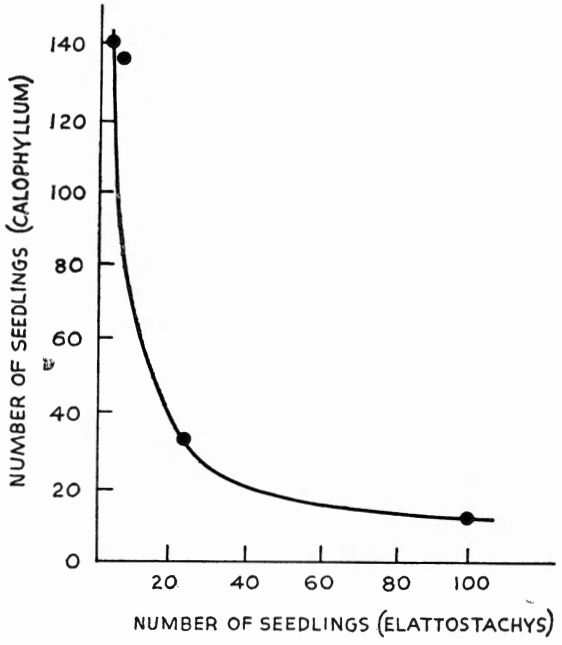

Figure 4. Dominance tendency of associated species in four observation plots of the *Calophyllum-Elattostachys* association.

is more abundant in dense and shady forest. On the other hand, the seedling establishment of *Cynometra* sp. is better in semi-open forest and that of *Dysoxylum richii* better in open forest. The latter species also establishes itself frequently in secondary forest which has been left undisturbed for some time.

In mature stands of the *Alphitonia-Rhus* association there is little seedling establishment of both species. *Elattostachys* seedlings, however, may be quite numerous in these forests. (See Figure 4).

Rhus taitensis is found as a pioneer among thickets of *Psidium guajava* and *Lantana camara* which have taken possession of overgrazed natural grasslands on the plateau.

The peculiar ability of certain species of *Rhus* to exude substances which hinder or exclude the growth of competitors has been observed in the United States and in Japan. The efficient pioneering ability of *Rhus taitensis* on 'Eua is probably based on the same mechanism. This is particularly interesting in view of the fact described by van Steenis (10) that certain species of forest trees are nomadic and others stationary.

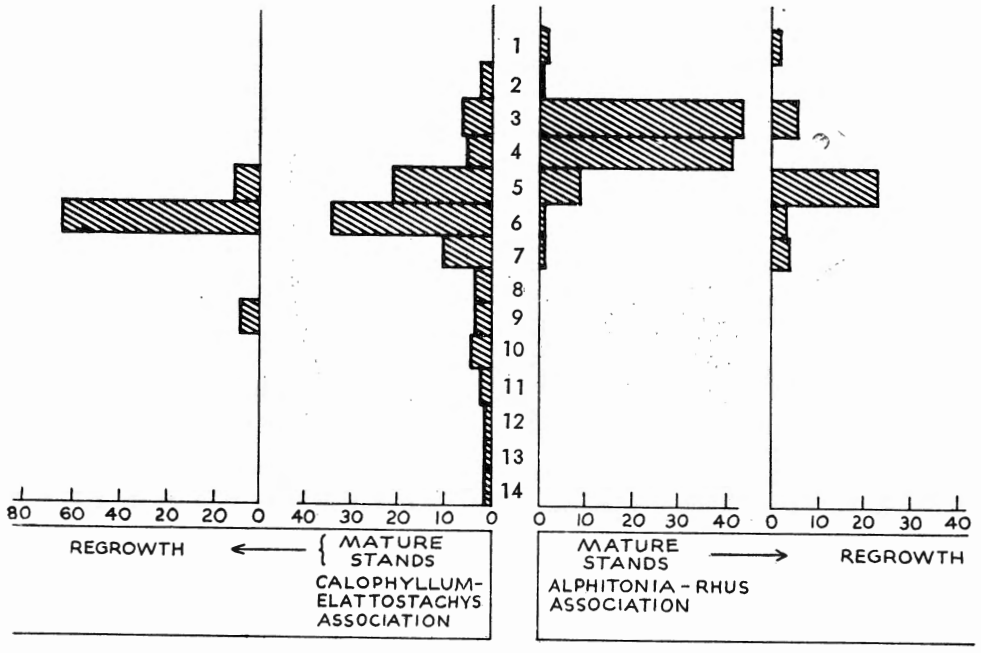

Figure 5. Species composition and regrowth pattern of two forest associations of 'Eua island. 1. Pleiogynium solanderi; 2. Grewia crenata; 3. Rhus taitensis; 4. Alphitonia zizyphoides; 5. Elattostachys falcata; 6. Calophyllum vitiense; 7. Dysoxylum forsteri; 8. Xylosma orbiculatum; 9. Garcinia myrtifolia; 10. Myristica hypargyrea; 11. Bischofia javanica; 12. Citronella samoensis; 13. Maniltoa amicorum; 14. Litsea mellifera.
(Scale of "mature stands" indicates average percentage species composition. Scale of "regrowth" indicates average number of established seedlings per tree for each species.)

Once *Rhus* has become established, *Alphitonia* often follows. It is difficult to forecast, however, if the same dominance combination of these two species will be found in the next generation. It is obvious from the present regrowth that the balance in the mature stands of the *Alphitonia-Rhus* association is changing in favour of *Elattostachys falcata.*

On the other hand, the regrowth in the *Calophyllum-Elattostachys* association proceeds generally in favour of *Calophyllum,* mostly *C. vitiense.* This points to an increased dominance of this species in the next generation (Fig. 5).

Apart from these spontaneous dynamic trends in each forest community there are the abrupt changes into secondary forest as a result of native farming.

Even in the Central Valley, the hygrophilous environment gradually changes in response to the spontaneous successions in the surrounding forest communities. But here again, over-grazing and erosion on the surrounding ridges cause a more direct and disastrous depletion of this special environment.

The Effect of Settlement

The history of settlement of 'Eua is a recent one. Before 1930 there were less than 500 people on the island. In the last thirty years, however, there has been a rapid increase so that at present, in 1961, there would be about 1500 people. This has caused an alarming increase in the land requirements for crops and in the timber requirements for building of houses and other constructions. Forest exploitation is advancing day by day. Formerly there were only spontaneous changes in the extent and in the composition of the forest communities. At present the changes are also man-induced and it is often difficult to separate the effects of spontaneous and anthropogenic changes.

Mention should be made here of the important study of Vasicek on the enrichment and impoverishment of faunas and floras in the Pacific (8) as a result of environmental changes in response to casual or recurrent processes.

Conclusion

Land clearing, ringbarking, firing, logging and crop-growing under increasing population pressure has resulted in drastic changes which cross-pattern the spontaneous dynamics of the virgin forests.

The adaptability of the endemic species and their efficiency of dispersal are unknown as are also the characteristics of their ecological niches.

A more detailed plant-sociological study would be required to solve the question as to how and where the environment of the endemic can best be preserved.

In this respect, the studies of Detling (11) on the role of environmental extremes and of Mason (12, 13) on the edaphic factor in endemism are of particular importance.

Preservation of the special habitats of the endemics must be based on a

sound understanding of the impact of forest successions and man-induced changes.

The present trend of these dual character changes indicates that 'Eua Island is on its way to becoming dominated by the secondary forest which is common to all the inhabited islands in this region.

The rapid growth of settlement of 'Eua would seem to suggest that the change will occur rapidly and that many of the endemic species are threatened by extinction in the near future.

Abstract

The delicate balance of environmental factors which determine the existence of endemic species is subject to spontaneous and man-induced changes.

Elevated islands in the Pacific often provide rare ecological niches for special floras. 'Eua island in the Tonga group is an example.

The primary forests of 'Eua display their greatest complexity in the hygrophilous environment of the Central Valley, in which more than fifteen rare or endemic plant species find their homes. The surrounding primary forests provide a protective zone around this particular environment.

Two major primary forest associations may be distinguished, viz. the *Alphitonia-Rhus* association [of *Alphitonia zizyphoides* (Solander) A. Gray and *Rhus taitensis* Guillemin] and the *Calophyllum-Elattostachys* association [of *Calophyllum vitiense* Turrill and *Elattostachys falcata* (Seemann) Radlkofer].

The described forest communities are unstable. The species composition of established seedlings is different from that of the parent stands.

Under undisturbed conditions light is the major controlling factor in these forest successions.

In the mature stands of the *Alphitonia-Rhus* association there are only a few established seedlings of these species and the composition proceeds in favour of *Elattostachys falcata. Rhus taitensis,* however, is a successful pioneer among low shrubs exposed to direct sunlight.

Seedling establishment in mature stands of the *Calophyllum-Elattostachys* association proceeds in favour of *Calophyllum vitiense,* particularly under shady conditions.

Apart from these spontaneous changes there are the more drastic changes caused by land settlement. Land clearing for indigenous farming is not done haphazardly. Useful trees are left standing and in addition some introduced trees are purposely planted. The resulting secondary forest is under some form of semi-management.

The adaptability of the endemic species and their efficiency of dispersal are unknown and also the characteristics of their ecological niches. A more detailed plant-sociological survey would be required to solve the question as to how and where the habitat of the endemic can best be preserved. Preservation of the special habitats must be based on a sound understanding of the effects of forest

successions and man-induced changes.

The present trend of these dual character changes indicates that 'Eua Island is on its way to becoming dominated by the secondary forest which is common to all the inhabited islands in this region.

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