ARBORICULTURE IN THE MUSSAU ISLANDS, BISMARCK ARCHIPELAGO[1]

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Lepofsky, Dana *(Department of Anthropology, University of California, Berkeley, CA 94720).* ARBORICULTURE IN THE MUSSAU ISLANDS, BISMARCK ARCHIPELAGO. *Economic Botany 46(2): 192–211. 1992. The Mussau Islanders of the Bismarck Archipelago in northeastern Papua New Guinea cultivate 26 indigenous tree species both for food and non-food uses in tree gardens surrounding the villages. Several trees which volunteer in these arboriculture zones are also tended and encouraged. I present ethnobotanical information on methods of cultivation, how and when the trees are harvested, preparation and use. The tree crop zone has a random spatial distribution overall, but some species within the zone are aggregated spatially. This clumping is related to the restricted habitat requirements of certain species, as well as individual species' reproductive traits. Coconut is the most frequent species in the arboriculture zone and is randomly distributed. Vertical stratification is attributable to the presence of a distinct herb layer and a subcanopy stratum of mature* Pandanus *spp. The stratification of some species pairs results from the deliberate planting of subcanopy trees next to canopy trees. The introduction of exotic garden species and the increasing availability of western packaged foods is changing the composition of traditional Mussau Islands tree gardens.*

El cultivo de árboles en las islas Mussau, Archipiélago de Bismarck. *Los isleños Mussau del archipiélago Bismarck en el noreste de Papuá Nueva Guinea cultivan 26 especies de árboles nativos para alimento y otros usos en los alrededores de los poblados. Algunos árboles que incidentalmente se establecen en estas zonas también son protegidos y cultivados. En este artículo se presenta información etnobotánico sobre métodos de cosecha, y preparación y uso de los árboles. La zona de cosecha de árboles en general tiene una distribución espacial al azar, pero algunas especies están espacialente agregadas dentro de la zona. Esta agregación está relacionada tanto a los requerimientos estrictos de hábitat como a las características reproductivas de determinadas especies. La palma de coco es la especie mas frecuente en la zona del cultivo de árboles y se distribuye al azar. La estratificación vertical se debe a la presencia de una capa característica de hierbas y a un estrato de subdosel de* Panadanus *spp. maduros. La estratificación de ciertos pares de especies es el resultado de la plantación deliberada de árboles del subdosel, cerca de árboles de dosel. La introducción de especies exóticas de jardín y la generalizada disponibilidad de alimentos occidentales empacados están modificando la composición de los cultivos de árboles de las islas Mussau.*

Key Words: arboriculture; Bismarck Archipelago, Mussau Islands, vertical stratification.

Although the Melanesian ethnobotanical literature concerning taro and yam cultivation is relatively rich (e.g., Barrau 1958; Sillitoe 1983), there are fewer studies of other cultivated or wild plant foods in the region. We know very little about the nature of tree cropping in Melanesia, the structure of tree crop gardens, or their role in the local economy. With the exception of Yen's (1974, 1976) work on the Santa Cruz Islands in the southeastern Solomons, a detailed study of arboriculture has not been conducted.

Tree crops have played a significant role in the diet since the time of the arrival of the earliest Austronesian speakers to island Melanesia (Kirch 1988, 1989). The Talepakemalai site, located on Eloaua Island in the Mussau Island group (Fig. 1), is the focus of a four year archaeological program investigating the Lapita complex (ca. 3600 to 2500 B.P.)—the ancestral culture of Austronesian speakers of the Pacific (Kirch 1984, 1989). Talepakemalai yielded thousands of anaerobically preserved plant remains representing more

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than 20 taxa of edible or economically important tree species. The realization that several of these trees are still cultivated on the island today, 3500 years after they were putatively introduced by the Lapita people (Kirch 1989), prompted this investigation of the arboriculture system on the Mussau Islands.

In the following pages I present an ethnobotanical description of the species which comprise the Mussau arboriculture zones, as well as general comments on tree-cropping on the islands. In addition, I examine the distribution of tree species within the zone, and whether there is vertical stratification among tree heights. The question of vertical stratification of tropical forests has a long history in the ecological literature (e.g., Halle et al. 1978; Jacobs 1988; Pompa et al. 1988; Richards 1952, 1983). Finally, I examine whether the planters of the tree gardens take advantage of the height differential between species, and how this compares with other examples of vertical intercropping in traditional agricultural systems in the tropics (e.g., Cristanty et al. 1986; Kirch and Yen 1982; Nations 1988; Nations and Nigh 1980).

The Study Area

The Mussau Islands (Fig. 1) are inhabited by Austronesian language speakers living in small hamlets along the islands' shorelines. Except for Mussau Island, which has a central volcanic spine, the islands are uplifted reefs. Most of Mussau Island is covered by dense primary tropical rain forest, and cultivation is limited to the island's periphery. Areas affected by shifting cultivation extend across much of the smaller islands. Only isolated patches of sparser primary forest remain on the smaller islands, growing on limestone outcroppings too infertile to cultivate (Fig. 2).

The traditional diet of the Mussau Islanders was varied, and took full advantage of the high species diversity of the land and ocean. Taro, yams, pigs, a variety of fish, and vertebrate and invertebrate marine organisms, as well as several cultivated tree crops were dietary staples (Nevermann 1933:83–84). According to Islanders, more opportunistic gathering of wild plants and the hunting of birds, fruit bats (*Pteropus* sp.) and cuscus (*Phalanger maculatus*) were also important.

Modern subsistence practices on the islands deviate from the traditional pattern because of dietary restrictions imposed by the Seventh Day

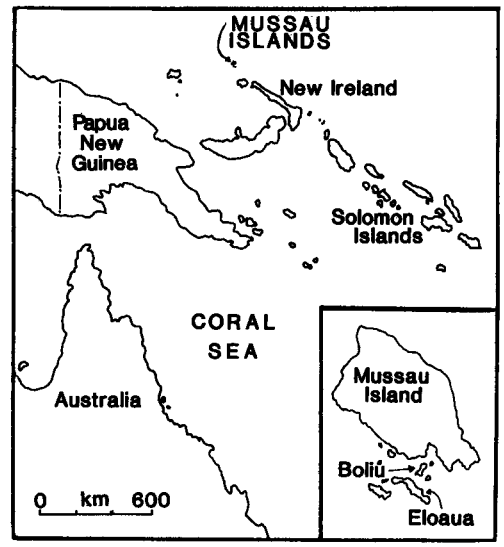

Fig. 1. Location of Mussau Islands in the Bismarck Archipelago.

Adventist mission church and the introduction of non-traditional foods. Following the dietary laws of Leviticus, the consumption of shellfish, fish without scales, pigs, fruit bats or cuscus, are prohibited by the church. In addition, the introduction of exotic plants, particularly manihot (*Manihot esculenta* Crantz, Euphorbiaceae), sweet potato (*Ipomoea batata* L., Convolvulaceae), papaya (*Carica papaya* L., Caricaceae), and watermelon (*Citrullus lanatus* (Thunb.) Mansfeld, Cucurbitaceae), and the increased availability of western packaged foods (particularly rice and canned foods), has had a major impact on traditional subsistence.

Despite these changes, many aspects of the traditional diet remain intact. Shifting cultivation of root crops, fishing, and planting and tending of tree crops still characterize today's subsistence pattern. A variety of tree crop species grow around the houses of all the hamlets, in many cases forming a distinct arboriculture zone (Fig. 2).

Methods

I obtained ethnobotanical information on tree cropping from interviews with locals knowledgeable in traditional plant use. Ave Male (AM) from Eloaua and Delma Joseph (DJ) from Boliu were my primary informants. Information provided by Ave and Delma was supplemented by casual conversations with other villagers, my own

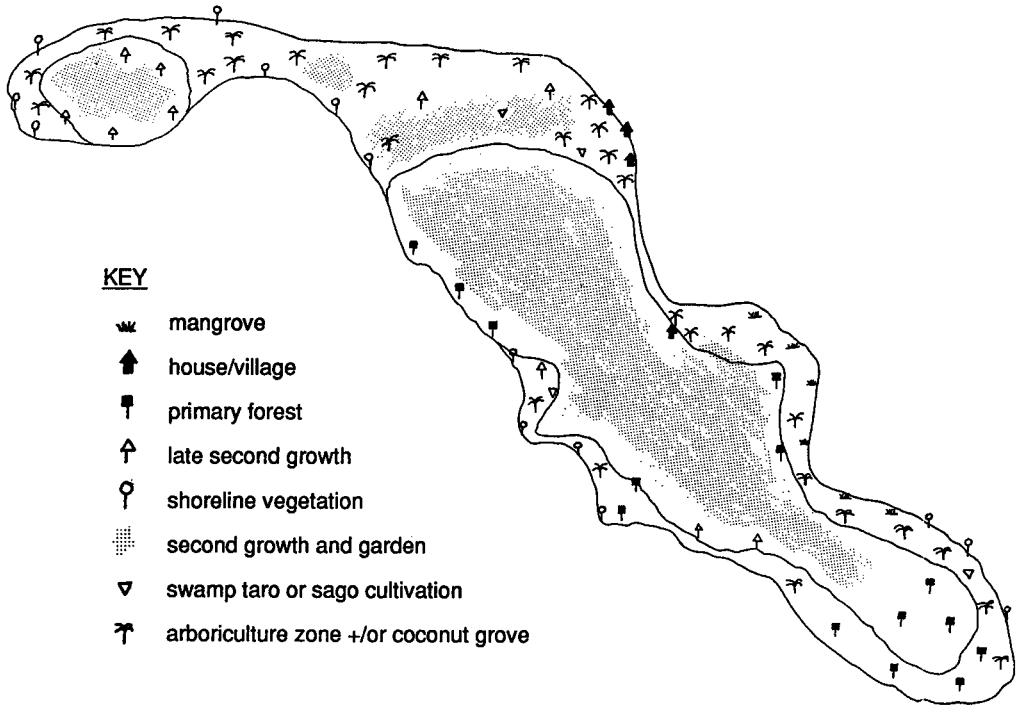

Fig. 2. Eloaua Island vegetation zones.

field observations, as well as an ethnography (Nevermann 1933) and a flora of New Ireland (Peekel 1984). Information on plant use was generally consistent between informants; any discrepancies are noted in the text and tables (i.e., Table 2). Voucher specimens of all tree crops except the most common and well known (i.e., *Cocos nucifera* L., Palmaceae, *Musa* hybrids, Eumusa section, Musaceae, and *Artocarpus altilis* (Park. ex Z.) Fosberg, Moraceae) are deposited at the B. P. Bishop Museum Herbarium in Honolulu.

Data used to describe the structure and composition of the arboriculture zone originate from transects and "profile-transects" from the arboriculture zone on Eloaua Island. I restricted my transects and profile-transects to areas of the arboriculture zone that locals consider to be planted in a traditional way. In transects 20 meters wide and running the length of the zone from the shore through the zone, I recorded all planted or tended trees whose canopies fell within the 20 meter wide transect. Species were enumerated in 5 meter intervals, in a total of 13 transects.

Profile-transects were 10 meters wide and ran the length of the zone. I mapped and identified all tended or planted tree crops, regardless of tree height, whose canopies fell within the transect. I categorized canopy shape according to basic geometric forms and took diameter breast height (dbh) and height measurements for all trees. Height measurements were done with a clinometer. I constructed five profile diagrams using a computer program with these field measurements as input.

The Tree Crops

Twenty six species of indigenous tree crops are cultivated in the arboriculture zones of Boliu, Eloaua and Mussau Islands (Table 1). Following Yen (1974:251), *Musa,* although not a tree, is also included. Volunteer trees and non-indigenous tree species growing in the arboriculture zone are treated in separate sections, below.

The discussion of tree crops is organized alphabetically by family. Unless otherwise cited, the source of the ethnobotanical information is from observations by the author, and/or is general knowledge among the villagers. How the tree is propagated, tended, and harvested and whether it was found archaeologically at the Telepake-

malai site, is summarized in Table 1. Season of harvesting is presented in a separate section.

ANACARDIACEAE

Dracontomelon dao (Papuan walnut). Mussau Islanders do not eat *Dracontomelon* fruits today, but they were eaten, although not preferred, in the recent past. The aversion to *Dracontomelon* fruits is not limited to the Mussau Islanders, as suggested by Peekel's (1984:323) observation that the New Irelanders reject it as food. I found only one *Dracontomelon* tree on the islands; all other trees had been recently cut down. The current disdain for the fruit contrasts with the archaeological record at Telepakemalai which yielded hundreds of *Dracontomelon* seeds.

Spondias dulcis. Spondias fruits are a favorite of children and pregnant women. The Islanders currently grow two varieties of *S. dulcis,* distinguished on the basis of fruit shape. There is a round variety ("malai") and a more elongated variety ("malai moso," so named because it is similar to the shape of "moso" [*Corynocarpus cribbeanus*]). A third, much larger variety ("malai to"; "to" = sugarcane) which was brought to Eloaua from Manus while I was there, is said to have grown on Eloaua in the past. *Spondias* fruits are a favorite food of cuscus; several fruits found at the base of the tree in the morning are half eaten by them. When they can be harvested, the young leaves of *Spondias* are eaten to alleviate hunger or sleepiness, presumably because they are quite tart.

BARRINGTONIACEAE (=LECYTHIDIACEAE)

Barringtonia magnifica. Today the people on Eloaua cultivate *B. magnifica* and *B. novae-hibernica.* The former is indigenous to the Mussau Islands and the latter originates on the island of Tench (AM). *Barringtonia* sp. fruits, a favored snack, are eaten by cutting the exocarp with a knife and removing the edible kernel. *Barringtonia* trees bear fruits two to five years after planting, depending on local growing conditions (AM). *Barringtonia* leaves are also used today to wrap foods for the earth oven.

BURSERACEAE

Canarium indicum. To obtain the edible kernel, the tough pericarp is placed on a hard surface and hit with a stone. The kernel is eaten raw or roasted over a fire. Roasted nuts can be stored for three to five months (AM). To my knowledge, the ability of *C. indicum* nuts to be stored for this length of time is unique among the island foods. The raw kernel can also be pounded until it is soft, mixed with a leafy green (*Abelmoschus manihot*) and baked in the earth oven (AM). Peekel (1984:585) noted that among the Namatanai (on the west coast of New Ireland), the nuts are pounded and formed into large cakes.

Today *C. indicum* trees only grow on the main island of Mussau. People were uncertain whether they could grow on the smaller islands, but thought the trees required the dark, more fertile soil of the big island. Traditionally, nuts from Mussau Island were traded to the smaller islands (AM). That the nuts can be preserved for several months, and the apparent restriction of the trees to the larger islands, makes them ideal trade items. *C. indicum* trees are seed-propagated by humans and are dispersed by pigeons.

Although *C. indicum* nuts were traditionally an important food on the Mussau Islands, they have fallen out of favor today. Those trees that I saw on Mussau Island were mature (judging from their height of over 30 meters); I saw none that were newly planted. The owner of one large, productive tree said he collected the nuts for his grandchildren to eat, but no longer bothered to eat them himself.

C. indicum trees have several other uses. The wood is prized for building, and the young bark, when eaten together with *Syzigium samarangense,* is supposed to take away hunger (AM). Nevermann (1933:75) observed children wearing carved *Canarium* nuts around their necks with lime filled engravings and holes drilled at both ends so they could be suspended by a string.

COMBRETACEAE

Terminalia catappa (sea almond). The nuts are a prized between-meal snack; fruits are often laid out to sun dry to facilitate breaking the tough fibrous exocarp enclosing the edible kernel; kernels are eaten raw or roasted. The leaves of *T. catappa* are used today to wrap foods for earth oven baking.

Two varieties of sea almond fruits are recognized as growing on Eloaua. One, said to have come from the nearby island of Emananus, has a soft exocarp that can be easily broken with teeth. The second has a hard exocarp which must be hit with a stone or cut with a knife to obtain the edible seed (AM). I was not able to get a

TABLE 1. MUSSAU ISLANDS TREE CROPS.

Scientific name (local name)	Plant use[1]	Cultivation treatment[2]	How harvested[3]	F.A.[4]
Dracontomelon dao (Blanco) Merr. & Rolfe (ANACARDIACEAE) (ra)	a	?[5]	?	Y
Spondias dulcis Soland. ex. Forst (ANACARDIACEAE) (malai[6])	a	?	A, C	Y
Barringtonia magnifica Laut. (BARRINGTONIACEAE) (alingasa)	a, c	1	B	N
Canarium indicum L. (BURSERACEAE) (osaosa)	a, d, e	1, 4	A, C	Y
Terminalia catappa L. (COMBRETACEAE) (paka)	a, d	1, 3, 4	B, C	Y
T. whitmorei Coode (aitabage)	a	1, 3, 4	A	N
Corynocarpus cribbeanus (Bail.) Smith (CORYNOCARPACEAE) (moso)	a	1	A, C	Y
Cycas rumphii Miq. (CYCADACEAE) (otou)	a, c, e	2, 4	?	Y
Diospyros peckelii Laut. (EBENACEAE) (aipa)	a, d	1, 3	A	N[7]
Pangium edule Reinw. (FLACOURTIACEAE) (suete, rumrum)	a, e	1, 3	A?, C	Y
Inocarpus fagiferus (Parkinson) Fosberg (LEGUMINOSAE) (iy[6])	a	1, 3, 4	?	Y
Artocarpus altilis (Park. ex Z.) Fosberg (MORACEAE) (ulu)	a, c, d, e	1, 3, 4	A	N
Paratocarpus venenosus (Zoll. & Mor.) Becc. (MORACEAE) (kaui)	a	1	A	N
Musa sections *Eumusa* and *Australimusa* (MUSACEAE) (uri[6])	a, c	2, 3	A	N
Syzigium aqueum (Burn. f.) Alston (bagalime)	a	1	A	N
S. malaccense (L.) Merr. & Perry (MYRTACEAE) (oa)	a	1, 3, 4	A	N
S. samarangense Bl. (kaviu)	a	1, 3, 4	A, C	N
Areca catechu L. (PALMACEAE) (buai)	e, d	?	?	N
Cocos nucifera L. (PALMACEAE) (niu[6], mami)	a, b, c, d	1, 3	A, C	Y
Pandanus conoideus Lam. & *P. engelerianus* Mart. (PANDANACEAE) (maroona, katai)	a	2, 4	A	N
P. dubius Spreng. (aum)	a, c, d	1	A	N
P. kaernbachii Warb. (yeri[6])	a, d	2	A	N

TABLE 1. CONTINUED.

Scientific name (local name)	Plant use[1]	Cultivation treatment[2]	How harvested[3]	F.A.[4]
P. tectorius Solms (arana)	a, d	1, 4	A	Y
Pometia pinnata J. R. & G. Forst. (SAPINDACEAE) (taono[6])	a, d, e	1, 3	A	N
Burckella obovata (Forst.) Pierre (SAPOTACEAE) (natu[6])	a	1, 3, 4	A, B	N

[1] a = food; b = beverage; c = leaves for earth oven baking; d = manufacture/construction material; e = medicinal, ritual or personal adornment.
[2] 1 = planted from seed or seedling; 2 = planted from vegetative cutting; 3 = tended by vegetation clearing and mulching; 4 = non-human dispersal—fruit bat unless otherwise noted in text.
[3] A = harvested by hand, either by climbing tree or from ground; B = harvested by knocking fruit with stick or thrown stone; C = harvested by picking up fallen fruits.
[4] F.A. = found archaeologically at Telepakemalai site; Y = yes; N = no.
[5] ? = information not collected or not known by informants.
[6] See text for individual variety names.
[7] *Diospyros* was incorrectly identified in Kirch 1989.

consistent answer whether the soft and hard varieties are regarded as "breeding true." One person responded that they did, but another thought that the soft variety which was brought to Eloaua now requires a stone to break the exocarp. People suggested the difference in soil type between Emananus and Eloaua caused the change in seed case hardness.

T. catappa start producing fruit four years after planting in rich soil (AM). "Wild" trees are dispersed by fruit bats into the forest and arboriculture zone. More commonly, the trees grow along the beach; these trees are seeded inadvertently by humans, or dispersed by fruit bats, or the ocean. There is much variation in fruit size within and between the wild and tended trees.

Traditionally, there were strict laws concerning who was able to harvest *T. catappa* trees (AM). Today *T. catappa* is eaten primarily by children, who make a game of throwing stones into the tree to knock down the fruits.

T. whitmorei is uncommon in the arboriculture zones of the islands. The fruits of *T. whitmorei* are eaten raw, or if very soft, roasted in charcoal. The seeds are eaten with coconut and fish, but they must be processed first to remove toxins. The wood is valued for canoes (AM).

CORYNOCARPACEAE

Corynocarpus cribbeanus. Four varieties are grown on the islands. These are distinguished by color (white, yellow, red and green), but not named. The fruit is either eaten raw, after removing the skin, or baked in the earth oven (even if underripe).

CYCADACEAE

Cycas rumphii. Seeds, which require processing before being eaten, were traditionally an important arboriculture crop (AM). Today *C. rumphii* is rarely planted or the seeds eaten. They may be propagated by planting cuttings, but most cycas in the arboriculture zone today are volunteers which are left and tended primarily because the leaves are used to wrap foods for the earth oven. Several 30 to 40 year old women whom I questioned had never tried *Cycas* seeds, and did not know how to process them.

Peekel (1984:35) reports cycas fruit resin and the kernel scrappings were used to cover small wounds, especially cuts. The ripe fruits were also used to make "humming nuts," a musical instrument (Peekel 1984:35).

EBENACEAE

Diospyros peckelii. Although reported to be an important food of the ancestors (AM), the fruits are not highly regarded today, and the trees are uncommon in the arboriculture zone. The fruit is eaten after the pubescent skin is removed, and the seeds are eaten after the seed coats are scraped off. It is said that a newly planted *D. peckelii* starts to bear after two to three years in good soil (DJ). Peekel (1984:433, 585) noted that New Irelanders used the hard, tough wood for shark fishing clubs.

FLACOURTIACEAE

Pangium edule. Although almost exclusively eaten by the older generation today, the fruits

and seeds were traditionally prized foodstuffs (AM). The Islanders grow two varieties of *P. edule*: a tough fleshed variety ("suete") and a softer variety ("rumrum"). The fruit skin is broken open and the flesh surrounding the seeds is eaten. The seeds are also eaten, but they must be processed beforehand. In addition to the usual method of leaching in the ocean, Peekel (1984: 384) noted that the seeds could be leached by being buried in sand for two to three weeks. Peekel also states that the flesh and seeds of the wild *P. edule* contain cyanide and are poisonous, but that the cultivated fruits are edible. According to Merrill (1981:154, 187), however, all seeds of this species contain hydrocyanic acid and are poisonous. Possibly Peekel was not aware that the cultivated *P. edule* seeds were processed before eating. I saw none growing wild.

P. edule seeds were traditionally used to make rattles for dancing bracelets and belts (Nevermann 1933:78; Peekel 1984:384). The leaves were crushed and squeezed for the juice which was dropped directly on wounds or on leaves to be used as a poultice (Peekel 1984:572).

Fabaceae/Papilionoideae

Inocarpus fagiferus (Tahitian chestnut). Two varieties, distinguished on the basis of fruit color ("iy lauva" and "iy"), are cultivated for their edible seed. The seed is prepared by baking the entire fruit in the earth oven and then removing the pericarp with a knife or teeth. Sometimes the pericarp is removed and then the nut is boiled, or roasted in the fire (AM; Peekel 1984:245). On Tench, a nearby island, people grate the raw kernel and then bake it in the earth oven, sometimes mixed with coconut cream (AM). The baked kernel can be stored for two or more days without spoiling (AM). The leaves are used to wrap sago (*Metroxylon sagu* Rottb., Palmaceae) for earth oven baking.

Moraceae

Artocarpus altilis (breadfruit). Breadfruit, a prized food among the Islanders, is baked in the earth oven or roasted in the fire. If the fruit is not quite ripe it is peeled before it is baked, or it is left to ripen in a basket and then baked. Alternatively, the insides of a ripe fruit are scraped out, mixed with coconut cream and then baked. Roasted breadfruit seeds are also considered to be a delicacy (AM). Peekel (1984:132) reports that the tree was protected from theft, presumably in a manner similar to coconuts (see below). In addition to reproduction by seed, breadfruit reproduces by sending up suckers from a main tree. Like other volunteers in the arboriculture zone, these shoots are either tended or removed from the tree garden depending on their location relative to other trees.

I observed breadfruits harvested by climbing the tree and cutting the fruit stem with a knife attached to a long stick. Traditionally breadfruits were harvested with a hook and net on a long stick which tore the fruits from the branches and then dropped them into the net (Nevermann 1933:99). Breadfruits must be harvested quickly when they are ripe or approaching ripe because of fruit bat competition. Women traditionally were responsible for the cultivation of breadfruits (Nevermann 1933:99). People maintained that breadfruits started to bear in five years after planting.

Breadfruit trees have several non-food uses. Today, the wood is prized for canoes (AM; Peekel 1984:134) and the leaves are used to wrap foods for the earth oven. Traditionally, the wood was also used to make large drums and planks (AM). The milky sap was used as birdlime as well as a base for dyes or powdered charcoal used to paint carvings and dance ornaments (Peekel 1984:134). The bark from young branches was pounded to remove the inner bark fibers which were used to fasten carrying baskets and to make handles (Peekel 1984:134).

Paratocarpus venenosus. The Mussau Islanders eat both the flesh and seed of *Paratocarpus.* The tough-skinned fruit is broken open and the flesh is eaten raw, but the toxic seeds must be leached before they are consumed.

Paratocarpus, like many of the fruits which require complex processing, is less popular than it was traditionally. I recorded *Paratocarpus* growing only on Mussau. At least one tree used to grow on Eloaua, but it was pulled out after several people became very ill and one child nearly died after eating unprocessed seeds. That several people were willing to eat the unleached seeds, is indicative of how little they had been exposed to eating *Paratocarpus.*

Musaceae

Musa, sections *Eumusa* and *Australimusa* (banana). At least 21 varieties of *Musa, Eumusa* type ("uri") are grown on the smaller Mussau

Islands. Additional clones may grow on Mussau Island itself, in the richer soil characteristic of that island. One informant said bananas grew everywhere on Mussau Island, but on the small islands would only grow where there are trees. The predominant varieties which grow in the arboriculture zones of the smaller islands are those that thrive in calcareous sandy soil and presumably are somewhat salt tolerant. Other varieties are grown in the gardens further inland. The varieties differ in color, shape and texture, and in how they are prepared. Some are eaten fresh as well as cooked, while others are only for cooking. Bananas are cooked by roasting in the fire or by boiling, sometimes with coconut cream.

Australimusa bananas, with their characteristic erect inflorescence, are cultivated today only on Mussau Island, but Ave thought they could grow on the smaller islands. *Australimusa* bananas are roasted in the fire before eating. The leaves of all varieties of bananas are used to wrap foods for the earth oven, and traditionally were used as "plates" for food (Peekel 1984:585).

Bananas are said to bear fruit four months after planting if the soil is good (AM). The initial flowers are removed to increase the number of fruits the plant will bear. According to Nevermann (1933:98) bananas were cultivated by both men and women.

Myrtaceae

Syzigium aqueum. Red and white varieties of *S. aqueum* fruits are cultivated on the islands. Like *S. malaccense* and *S. samarangense,* the varieties are not distinguished by local name. Today, few *S. aqueum* trees grow on the smaller islands, but are relatively common in the arboriculture zones on Mussau Island. *S. aqueum* fruits are eaten raw.

S. malaccense. According to Peekel (1984:335), *S. malaccense* fruits were the most prized of those eaten in the Bismarcks. Today on Eloaua *S. malaccense* is not common enough to be of major importance, but none-the-less the fruits, which are eaten raw, are highly valued. Red and white varieties of fruits are cultivated, but not named. *S. malaccense* is said to grow best in dark, soft soil, and for that reason, the fruit bat dispersed trees growing in the forest produce many fruits. Only seeds from sweet *S. malaccense* fruits are selected for cultivation.

S. samarangense. This species is prominent in the arboriculture zone and forests surrounding the villages. The Islanders recognize six varieties of fruits, which they distinguish by color and shape (green, white, red, and long and short of each), but not name. The fruits, which are eaten raw, are said to be good eaten with scraped coconut meat. The bark of *S. samarangense* branches, eaten with *T. catappa* nuts, is also a favorite food.

Because there are many of these trees on the islands, and diverse fruit qualities from which to choose, only those seeds from sweet fruit (i.e., few seeded and thick fleshed), are planted; the varieties are said to breed true (AM). Those trees growing along the beach are either planted by humans, dispersed by fruit bats, or by ocean currents; those growing in the forest are fruit bat dispersed.

Palmae

Areca catechu (betel nut). As in most of Melanesia, the chewing of betel nut played an important social role in traditional Mussau Island society, but was forbidden by the mission church in the 1930s (AM). *Areca* palms were cut down on all the smaller islands, but according to the elders, before the time of the church betel palms were planted close to the houses and were tended like other arboriculture species. The chewing of betel is seeing a current revival among the younger (predominantly male) members of the communities.

Betel nut is chewed in combination with burned lime and the leaf of *Piper betle.* The exocarp of *Areca* fruit is stripped off with the teeth and a portion, or the whole kernel is chewed. Once the seed is masticated, a rolled piper leaf is dipped in lime and the coated end is chewed with the betel nut. The chewing of the three ingredients together produces a bright red juice which has a mild intoxicating effect when swallowed. The brightness of the juice color and the strength of the intoxicant increase with increased chewing time.

Traditionally there was much ceremony involved in betel chewing. Men carried their own supply of betel in net bags, and two chiefs would exchange betel with each other in greeting ceremonies (Nevermann 1933:108). The lime for betel chewing was carried in sometimes elaborately decorated gourd containers (Nevermann 1933: 108).

The betel palm had a variety of other uses. Peekel (1984:586) reported that the wood was

used for spears. Nevermann (1933:82) noted women wearing belts made of betel inner bark painted with a yellow dye (probably *Morinda citrifolia*).

Cocos nucifera (coconut). Coconuts are certainly among the most prized of the tree crop species, and are a staple in the island diet. They provide a variety of food and non-food resources and are a common component of the arboriculture zone. Two general varieties of coconuts are cultivated on the small islands (I did not enquire about additional varieties growing on Mussau Island).

The first variety ("niu"), has a red-skinned ("murai") and green-skinned ("nusoa") form. "Niu" nuts provide several kinds of food. The "meat" of mature nuts is eaten raw, especially with seaweed (*Caulerpa* spp.), or grated and made into coconut cream. The cream is regularly added to all foods, especially pan fried fish, and to manihot and fish baked in the earth oven. The cream adds a rich flavor to the otherwise bland taste of manihot, and for that reason is a dietary staple today. As many as 10 or 15 coconuts are used to render cream for a single earth oven baking event. Peekel (1984:65) notes that grated meat is also added directly to food. Nevermann (1933: 84) states that it was forbidden for women to eat grated coconut and they could only eat meat scraped from the shell with a spatula. The liquid inside young coconuts is often drunk, especially when away from the village and without fresh water. The sprouting stem and spongy substance which fills the cavity of a germinating "niu" nut are also important "bush foods," but since they are quite rich are generally eaten in moderation. The leaves of the sprouting coconuts are a favorite for wrapping foods for earth oven baking. Today, mature "niu" nuts are processed for copra, one of the few sources of cash income for the Islanders.

Only the fibrous husk (mesocarp) of the second variety of coconut ("mami"), provides food. The outer skin is removed and the husk is chewed for its sweet juice. People who are ill chew "mami" to remove a bad taste in the mouth (AM).

Coconuts are propagated by planting a dry nut with the "eye" into the ground and leaving the nut until it has sprouted. At that time, if desired, the nut is transplanted into another hole and the shell is only partially covered. When the young palm grows bigger, the entire nut is covered. Judging from the angle of some of the coconut trees in the arboriculture zone, coconuts are also left to grow wherever they fall, regardless of the angle at which they sprout. Nevermann (1933: 96) saw a y-shaped piece of wood stuck in the ground to support a particularly bent over coconut tree. Sprouting coconuts found on the beach are also planted; Nevermann (1933:96) noted that such sprouting coconuts were often stored for future planting. He also observed newly planted coconuts surrounded with small fences for protection, presumably against pigs.

Several informants said that it was especially important to keep a coconut palm's bole clear of vegetation throughout its life or it would not grow or bear fruit. If tended, and the soil is good, it is thought that the trees will bear in five years, but otherwise it can take up to nine years to produce (AM). Nevermann (1933:97) states that men, often chiefs, were responsible for cultivating coconuts; today both men and women grow coconut palms.

Coconut palms provide several non-food resources. Coconut leaves are woven into baskets and into mats for walls and roofs of temporary structures. The dried leaflet ribs are bound together for brooms. Traditionally, the thick sap of *Artocarpus* was smeared on the leaflet ribs as birdlime (Peekel 1984:586), coconut shells were used to carry water or lime (Peekel 1984:586; Nevermann 1933:100), and the husk fibre was used to make floor matting, brushes and rope (Peekel 1984:65).

Coconuts were traditionally guarded against theft because they were so highly valued. Nevermann (1933:97) observed several different taboo signs on coconut palms to prevent the coconuts from being stolen. The most severe of the taboo signs, observed on palms on Mussau Island, involved wrapping the tree trunk with the thorn covered stem of an unidentified plant. Nevermann also observed palms on Tench Island with obstructions high in the trees made of large twigs interwoven like large bird's nests.

Today the Islanders rarely use taboo signs to restrict others from harvesting coconuts. I observed one palm marked with a taboo sign. Upon discovering this tree, my companions remarked that the owner was not a good man. It is common to harvest coconuts belonging to other people when they are encountered growing at a distance from the village, but it is expected that the owner will be told and thanked.

PANDANACEAE

Pandanus spp. The Mussau Islanders use several *Pandanus* species for a variety of purposes, but only five species are actually cultivated. I observed two *Pandanus* species (not further identified) in the arboriculture zone on Eloaua which were transplanted from other areas. Two local wild species are regularly left if they volunteer in the arboriculture zone and the Islanders use several other *Pandanus* species growing on Mussau Island for various purposes. Unlike many of the other arboriculture species, none of the *Pandanus* species are mulched with organic waste. The leaves of some species are used to make different kinds of mats, and the stilt roots of at least one species are folded over and made into tongs for handling hot rocks. There is no indigenous term for the genus *Pandanus,* although people recognize the similarity among all *Pandanus* species.

P. dubius. Keys are collected primarily for the fleshy skin on the basal end of the key; they are chewed raw, or baked in the earth oven. The keys can also be cut in two to remove the seeds, which are eaten raw. Although traditionally the Islanders regularly ate *P. dubius* seeds (AM), I observed only one instance of people eating the seeds, which was probably prompted by my questioning.

P. dubius seedlings grow from keys intentionally planted, those which people discard after eating, fruit bat dispersed keys, and self propagation. The plants appear to prefer shade.

The leaves of *P. dubius* serve many purposes. Most important today, they are used to wrap fish and manihot for earth oven baking. Because the leaves are wide and strong, they can hold moisture in "like a saucepan." Many of the *P. dubius* grown in the arboriculture zone are raised specifically for their leaves; the leaves of the smaller trees in the zone often are cut for this purpose. The leaves are also used to wrap taro to be softened by being stamped on. In addition, the leaves are used as floor or wall material and loose thatching for roofs (Peekel 1984:41), and traditionally they were folded into packets for carrying lime for betel chewing (Peekel 1984:41, 585).

Other *P. dubius* parts provide useful materials. Stilt roots are made into tongs to remove hot stones from the earth oven, and fibres from inside the roots are extracted, dried, and then woven into mats. Finally, part of the inner main stem is used as roofing material for houses.

P. conoideus and *P. engelerianus.* The Islanders use these two similar *Pandanus* species in the same way. Both species have long cylindrical heads, which, when ripe, are a striking deep red. The two species differ in appearance in that *P. engelerianus* is larger in all parts. The heads of both species are baked in the earth oven or boiled, and the pulp is removed from the seeds to render juice. The juice is eaten mixed with other foods, particularly taro and manihot. Traditionally, the rendered juice was put in a large bivalve shell between important men. The men dipped small balls of beaten taro into the juice and had a contest to see who could eat the most; the combination is supposed to have strong laxative properties (AM).

These two species grow best in shaded, wetter areas with rich soil. One informant (DJ) thought that in addition to purposeful planting, *P. cominsii* and *P. conoideus* grow wild as a result of dispersal of seeds by birds.

P. kaernbachii. Several varieties of *P. kaernbachii,* distinguished by the color of the globular head and whether seeds are present, are grown on the islands. The seeded varieties are yellow ("yeri malao") or red ("yeri tui tui"). A third variety has no seeds and seems to be almost exclusively red ("yeri kapakatuna"), although everyone thought yellow seedless varieties (also called "yeri kapakatuna"), were possible.

P. kaernbachii prefer to grow where there is much water, the soil is rich, and there is shade. They can be planted quite close to one another. Ave thinks it takes three to five years for a *P. kaernbachii* planted in poor quality soil to bear fruit, but only one year in rich soil.

Only the two keys of *P. kaernbachii* are eaten. The fleshy, somewhat sweet skin at the attachment end of the key is chewed, leaving a fibrous quid. The keys are eaten raw, boiled, or baked in the earth oven, sometimes with coconut cream. The leaves are also used to make mats.

P. tectorius. An important snack food, it is not uncommon to see someone coming home from a day in the garden carrying a ripe *P. tectorius* head. The fleshy skin of *P. tectorius* keys are usually eaten raw, but sometimes are boiled in water to render juice. Most people recognize that *P. tectorius* seeds are also edible, but I only saw the seeds being eaten once, on my behalf. The seed's unpopularity may have to do with their small size, and that the seeds are often insect eaten.

P. tectorius are propagated by seed. Although people sometimes plant *P. tectorius,* it seemed to me that the majority of the *P. tectorius* trees growing in the arboriculture zone, and certainly in the taro gardens, started from keys which people discarded after eating. The *P. tectorius* growing in the forest are fruit bat dispersed. One informant (DJ) recognized that there are male and female *P. tectorius* (i.e., that they are dioecious).

People also snack on *P. tectorius* stilt roots ("suraki"). Roots which have not yet reached the ground are chewed for their water, after the outer skin is removed. Alternatively, the roots are baked in the earth oven or roasted in the fire until soft. The skin is left on while cooking, but is removed before the roots are eaten.

P. tectorius leaves are its most valued part because they are used to make the most common mat type in the villages. While I was on Eloaua all the women of the village collected *P. tectorius* leaves for mats on the same few days in October. When I asked why everyone gathered the leaves at that particular time, people simply responded that it was the right time to do so. The leaves of *P. tectorius* are also woven into loose thatching for roofs (Peekel 1984:585), as well as rain capes. The inside of the main stem is used for roofing (AM).

Sapindaceae

Pometia pinnata. Large *P. pinnata* trees are prominent in the arboriculture zones and forest near the villages. Peekel (1984:335) states that after *Syzigium malaccense,* this is the most valued of the fruits in the Bismarcks, an observation borne out by the enthusiasm of the Eloauan people around flowering time. Two fruit varieties are grown on the islands—a red skinned ("taono ulupaka") and a white skinned ("taono") variety. The plants are said to grow quickly, and begin to bear fruit within five years (AM).

To eat the fruit the thin skin is peeled and the inner flesh (aril) consumed. The seeds must be leached in salt water before being eaten. Because I was not on the islands when the *Pometia* were fruiting, I did not observe whether the seeds are regularly consumed today, or have fallen out of favor like other seeds which require complex processing (i.e., *Cycas, Pangium, Paratocarpus*). *P. pinnata* is said to carry fruit for only short periods.

The strong wood of *P. pinnata* is prized for house construction (AM) and the bark is used to attract small fish to be caught in a net (DJ). The Namatanai people of New Ireland put seed scrapings and the aril on burns (Peekel 1984: 572).

Sapotaceae

Burckella obovata. The fruits are eaten raw, roasted in the fire or, if they are particularly juicy, baked in the earth oven. The Islanders grow two varieties of *Burckella,* differing in fruit and leaf shape. "Natu" is large-leafed and has long fruits, and is the more common of the varieties in the arboriculture zone. "Natu pipirua" (named after "pipirua," the round fruit of *Xylocarpus moluccensis*) is small-leafed and round fruited. The varieties are said to breed true (AM).

Harvesting Times

My attempts at gathering information on harvesting times were not very successful. The Islanders are not concerned with calendar time as we are, and as a result my queries concerning timing often met with inconsistent answers. Additional problems arise from variation in fruiting times between microhabitats and varieties, and the presence of stragglers on the trees which considerably extend the fruiting periods.

The Islanders do keep track of fruiting times in relation to the timing of other trees. According to Ave Male, the fruiting of breadfruit was important for keeping track of the fruiting cycle of several of the arboriculture trees. In a series of fruit trees reported to be on a six month fruiting cycle (*S. malaccense* followed by *Pometia pinnata* and then *S. samarangense*) breadfruit is the last to fruit. Once it is finished, the cycle starts over again with the fruiting of *S. malaccense.*

The seasonality information I was able to gather from interviews, my own observations (during September to December field season), and Peekel (1984), is summarized in Table 2. Discrepancies between observations by Peekel and myself are likely attributable to variation in fruiting times on different islands in the Bismarcks. The lack of consensus from all sources can only be resolved by careful observation throughout an entire yearly cycle.

Encouraged Volunteers in the Arboriculture Zone

Economically important trees which volunteer in the arboriculture zone are often allowed to grow with the cultivars (Table 3). Whether these

TABLE 2. FRUITING TIMES OF ARBORICULTURE SPECIES.[1]

Species	No. fruiting times/yr	Months observed fruiting											
		J	F	M	A	M	J	J	A	S	O	N	D
Dracontomelon dao	?[3]			p	p	p[2]			p	p	p[2]		
Spondias dulcis	2	p[2]						p[2]	l	l	l	l	l
Barringtonia magnifica	c	c	c	c	c	c	c	c	c	c	c	c	c
Canarium indicum	2											l	
Terminalia catappa	1, 2											l	
T. whitemorei	2												
Corynocarpus cribbeanus	2											l	
Cycas rumphii	?												
Diospyros peckelii	1, 2, 4					p	p					l	l
Pangium edule	2	p	p					p	p			l	l
Inocarpus fagiferus	2											l	
Artocarpus altilis	2				p	p					l	l	
Paratocarpus venenosus	2											l	l
Syzigium aqueum	2											l	l
S. malaccense	2	p[2]			p	p				l			l
S. samarangense	2								l				l
Areca catechu	c	c	c	c	c	c	c	c	c	c	c	c	c
Cocos nucifera	c	c	c	c	c	c	c	c	c	c	c	c	c
Pandanus conoideus	?				p							l	l
P. engelerianus	?											l	l
P. dubius	?											l	l
P. kaernbachii	?							p[2]				l	l
P. tectorius	?											l	l
Pometia pinatta	?	p, l[2]							p[2]				
Burckella obovata	2							p[2]		p[2]		l	

[1] Informants provided number of fruiting times per year. More than one number indicates disagreement among informants. Under Months Observed Fruiting, p = Peekel (1984), l = Lepofsky field observations, c = Continuous fruiting (from a combination of my field observations and interviews). No observations were made for species with no information under Months Observed Fruiting.

[2] Fruiting time inferred from flowering time.

[3] ? = information not collected or not known by informants.

trees are allowed to grow depends on their location relative to the cultivars and the usefulness of the volunteer trees to the gardener. If a volunteer tree isn't wanted it is removed when the tree garden is cleared of other unwanted vegetation. Some of the volunteers which are allowed to grow are tended by clearing surrounding vegetation to prevent overcrowding. Table 3 is not an exhaustive list of encouraged volunteers; it is simply a list of trees I observed growing in the zone. Presumably any valued tree that volunteers in the zone could be left and tended as is evidenced by the wide range of trees and uses represented in the table.

INTRODUCED SPECIES

The introduction of exotic plants to the islands has changed the composition of the arboriculture zone. Introduced fruit trees are interspersed among the indigenous varieties. Introduced species include those that are indigenous to Melanesia, but not to the Mussau Islands (e.g., *Barringtonia novae-hibernica*), and those that are more exotic. Lemons (*Citrus limon*) and papayas are common components of the tree crop zone. On Mussau Island, cashews (*Anacardium occidentales*), starfruits (*Averrhoa carambola*) and Jack-fruits (*Artocarpus heterophyllus*) are planted among the indigenous fruit trees.

A variety of ornamentals, predominantly *Plumeria,* are among the more common introduced species. These flowers play an important social role. They not only serve to beautify the village, but are also used to decorate the mission church for Sabbath services. Ave's status was enhanced by the fact that he was the primary supplier of the church flowers.

The exotic species are integrated into the traditional tree gardening system. Cuttings from desirable plants are transplanted into the tree crop

TABLE 3. ENCOURAGED VOLUNTEERS IN THE ARBORICULTURE ZONE.

Scientific name (local name)	Food use[1]	Non-food use
Antidesma moluccanum Airy Shaw, EUPHORBIACEAE (salovovo)	fruit (R)	wind protection, dye (berry)
Glochidion novoguineense K. Schum. (airai)	—	wind protection, shade, live ladder, fuel
Garcinia ledermanii Laut., GUTTIFERAE (angoai)	fruit (R)	live ladder
Intsia bijuga (Colebr.) Kurtze, LEGUMINOSAE (qwila)	beans (P)	wind protection, construction, fuel
Antiaropsis toxicaria Lesch., MORACEAE (maki)	fruit (R); seed (P), leaf[2]	construction, fuel
Ficus sp., MORACEAE (aikisongo)	leaf (R)	ornamental, sand paper (leaf)
Ficus copiosa Steud. (utau)	fruit (R), leaf[2]	—
Ficus pseudomassa Corner (tekatekagila)	leaf[2]	—
Hydriastele kasesa (Laut.) Burret PALMACEAE (aurasa)	vegetative shoot (P)	mats (leaves), flooring (bark)
Pandanus sp., PANDANACEAE (saigelai)	—	mats (leaves)
Premna integrifolia L., VERBENACEAE (alo)	—	shade

[1] R = raw, P = processed.
[2] Used to wrap food for earth oven baking.

zone and ownership of introduced species is treated the same as indigenous plants.

OWNERSHIP OF TREE CROPS

Although seemingly clear to the locals, rules concerning ownership of tree crops appear haphazard and ill defined to the outsider. What follows is my understanding, after numerous questions, of general tendencies concerning tree ownership. The discussion applies to indigenous as well as introduced cultivars.

Ownership of cultivated trees in the arboriculture zone itself is fairly straightforward: the person who plants the tree is the owner. If the planter does not own land in the arboriculture zone, he or she must ask permission to plant from the land owner. Permission always seems to be granted to members of the same clan as the owner. After the owner of the tree dies, the tree belongs to the tree owner's children, regardless of who owns the land. If there is more than one child, it belongs to the person who is living closest to that tree. Ownership of trees which volunteer in the arboriculture zone is less clear, but it seems that a tree can be tended by whomever finds the volunteer as long as the owner of the land doesn't object.

Ownership of fruit trees which volunteer on owned forested land generally depends on how close the tract of land is to the village. The harvest from a wild fruit tree growing at a distance from the village generally belongs to anyone who happens by the tree during fruiting. If someone chooses to clear and tend the tree, the harvest belongs to that person. The owner of the land apparently has little say because of its distance from the village. If the owned land is close to the village (i.e., more actively used), the wild fruit trees are the property of the land owner, and no one should tend or harvest the tree without permission from the land owner. A tree which is encountered while clearing a garden, regardless

of who owns the land, belongs to the person tending the garden.

Although land and tree tenure appear complicated, all queries about the ownership of individual trees brought consistent answers. Planting and tending of trees signifies ownership. Only very loosely is there any connection between the ownership of individual trees and the land on which they happen to be growing.

Quantification of the Arboriculture Zone

I determined the relative abundance of each tree crop by tabulating the relative frequencies of all species in 13 transects from Eloaua's arboriculture zone. Coconuts dominate the arboriculture zone, followed by *Pandanus dubius,* then the combined "other" (encouraged volunteers) category, followed by papaya, *Pandanus tectorius* and bananas (Fig. 3). All other species are under 5% each.

Although the dominance of coconut may have been increased by recent dietary changes, it was probably the main component of traditional arboriculture zones as well. Nevermann's (1933) observations of the islands before the mission church or major contact with the western world suggest that coconuts were of primary importance at that time. Photos from that time also indicate that coconuts were a dominant species in the tree crop zone. The elaborate taboo system around coconut palms, and that they were frequently owned by chiefs, further suggests their special importance. In addition to providing a highly caloric, pleasant tasting food, coconut palms are valued for the variety of materials they supply for many everyday uses.

Because most of the other species are similar in abundance, and productivity and harvesting patterns are unknown, it is difficult to assess their relative importance. *Pometia,* which regularly grows to 30 meters, can not be directly compared to a 12 meter *Barringtonia* sp. without corrections for per tree productivity.

Are individual species within the arboriculture zone or all trees in the zone as a whole distributed randomly? I used a Standardized Morisita Index (SMI; Krebs 1989) to examine the distributions of tree species in the 13 transects. A Standardized Morisita Index is an index of dispersion where −1 is maximum uniformity, 0 is randomness, and +1 is maximum aggregation.

The results of the analysis for all species in all transects indicate that the zone as a whole has a random distribution (SMI = .23). The spatial distribution of individual species is more difficult to determine because of inadequate sample sizes for many species. Coconut palms are distributed randomly (SMI = .05) and *P. dubius* and *P. tectorius* are spatially aggregated (SMI = .49 and SMI = .47, respectively). I did not examine quantitatively the spatial distribution of introduced tree crops.

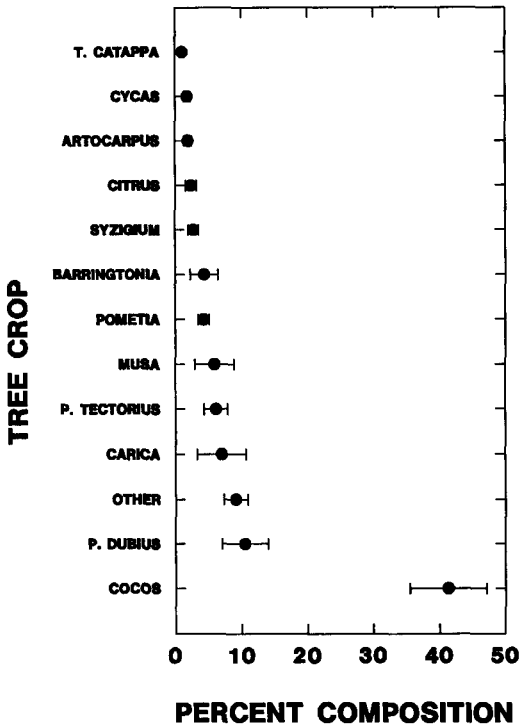

Fig. 3. Percentage composition and standard errors of the common tree crops. "Other" = encouraged volunteers. *Citrus* is introduced lemon. Cultivars <1% of the total are not included. These are *Burckella, Pandanus conoideus, P. kaernbachii, P. engelerianus, Pangium,* and *Syzigium malaccense.* Their total is 1.73%. T. CATAPPA = *Terminalia catappa*; P. TECTORIUS, P. DUBIUS = *Pandanus* spp.

The statistical analysis confirms my field observations that, although the trees in the zone as a whole are randomly distributed, certain species occur together in clumps. This was particularly striking for the *Pandanus* species. The aggregation of pandanuses may be attributed to several factors. According to informants, species of *Pandanus* are more likely to grow in wetter, shaded areas (except for *P. tectorius*), with rich organic soil. It may be that pandanus plants are delib-

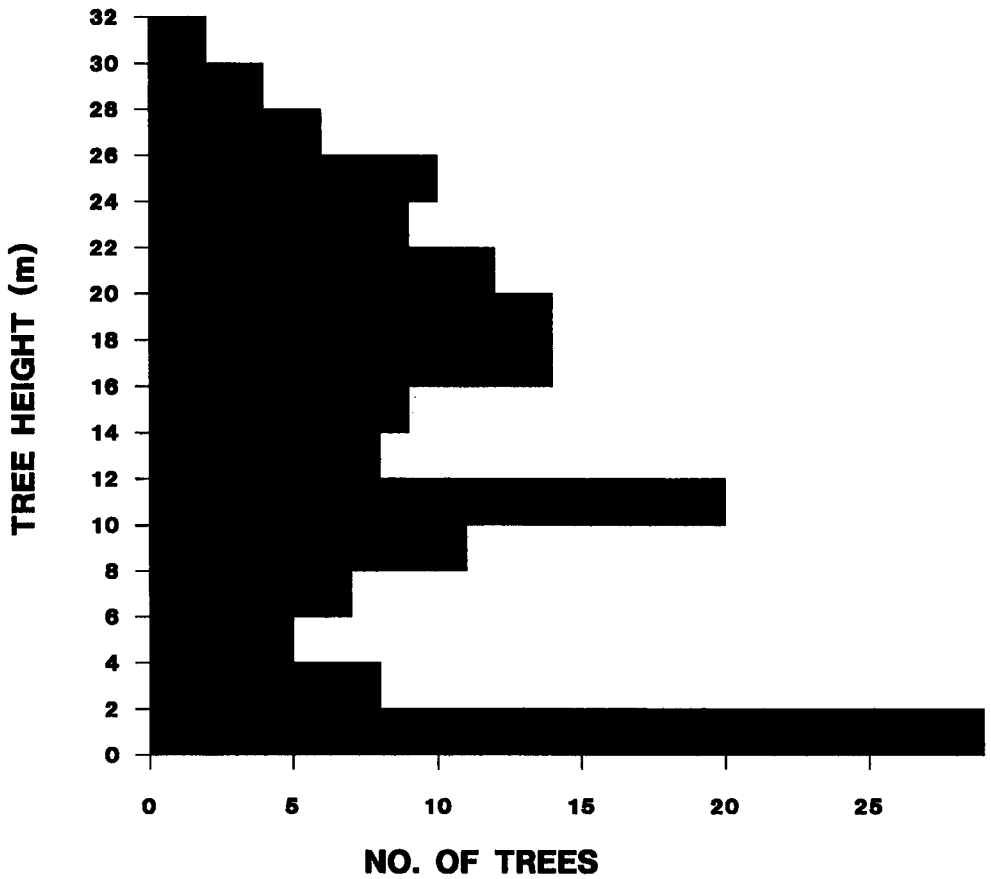

Fig. 4. Frequencies of tree heights from profile-transects.

erately planted in areas which are more moist, or nutrient rich. Alternatively, the clumped distribution of *P. dubius* as well as *P. tectorius* may be related to a short natural dispersion distance of the large fruits, and the pattern of consumption by the Islanders. Since several keys are often eaten at a single sitting, discarding them together into the arboriculture zone would result in a cluster of trees. Finally, the aggregation of pandanuses may simply be related to the fact that the trees have a limited canopy, and do not have extensive root systems, and therefore can be planted close to one another.

To determine whether there is vertical stratification in the arboriculture zone, I plotted the combined frequencies of tree heights from the five profile-transects (Fig. 4). The histogram shows a tri-modal distribution indicating that the zone is characterized by three strata: an understory layer (<5 meters), a subcanopy layer (5–14 meters) and a canopy layer (14–32 meters). The subcanopy layer is dominated by mature *Pandanus* spp. (58%).

The profile diagrams (Fig. 5) provide the additional qualitative data to assess the nature of the stratification of tree species in the arboriculture zone. That is, is there a consistent spatial relationship between the species of the canopy and subcanopy strata? We know that the subcanopy stratum is dominated by mature pandanuses, and that species of this genus are spatially clumped along the profile. If vertical stratification is a result of consistent relationship between canopy and sub-canopy species, we should see clusters of pandanus planted directly under certain canopy tree species.

The profiles suggest that only *P. dubius* is stratified relative to the canopy, and that they usually occur directly underneath a coconut palm (*P. dubius* and *P. tectorius* are the only *Pandanus* species found in the profiles).

To determine whether the apparent stratifi-

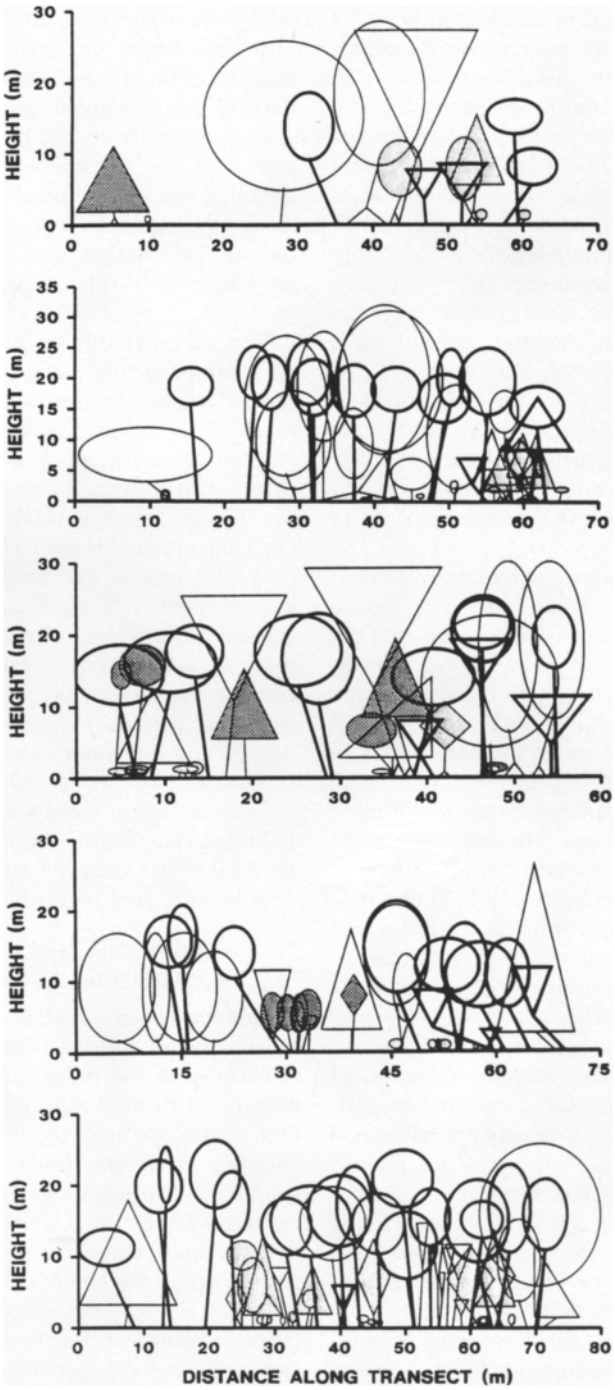

Fig. 5. Profile diagrams of Eloaua arboriculture zone. Three species are identified. Individuals with any canopy shape and bold outline are *C. nucifera.* The two *Pandanus* species are shaded as indicated in the figure legend. The profiles began at zero meters at the shore and extended inland.

cation of *P. dubius* relative to coconut is real, I examined the frequency with which *Pandanus* occurred with and without coconuts relative to the abundance of coconut in the canopy. There were 45 *P. dubius* in the profiles directly underneath a coconut, and two *P. dubius* which were not directly underneath a coconut. Forty-eight of a total of 83 canopy trees were coconuts. *P. dubius* are planted underneath coconuts more often than is expected by chance (χ^2; $P < .0001$). *P. tectorius* show no relationship to coconuts (six *P. tectorius* planted underneath a coconut, eight not directly associated with a coconut; χ^2; $P = .05$). I also calculated a χ^2 for the distribution of *P. dubius* relative to *Pometia,* the next most abundant canopy tree. Six *P. dubius* are underneath *Pometia,* 41 are not. Ten of the 83 canopy trees are *Pometia.* These two species are not significantly related (χ^2; $P = .05$).

It appears that *P. dubius* is frequently planted under coconut palms. Since mature *P. dubius* plants are generally about 10 meters tall, and the bottom of the canopy of mature coconut palm is generally 10 to 15 meters above ground, the two species are well suited to be members of stratified pairs. Furthermore, the narrowness of the pandanus canopy, its preference for shade, and the absence of branches on the main stem of the coconut palms, means that the two can be planted close to one another. No other species pair has these characteristics. My field observations suggest that this relationship also holds true for *Pandanus* species other than *P. tectorius.*

The planting of pandanus close to coconuts seems to be planned. When asked why he would plant pandanus so close to a coconut (which may not have been full grown itself) Ave explained that the two would grow up to different heights.

This planned stratification may not be limited to species of pandanus, but I was not able to collect sufficient data to test this pattern for other species. I did observe a *Syzigium aqueum* being planted underneath a coconut. When I asked Ave about it he explained that the *S. aqueum* at maturity would be smaller than the coconut.

The purposeful planting of cultivars in multistoried associations is a common practice among tropical peoples. The Lacandon Maya of Mexico (Nations 1988; Nations and Nigh 1980), the Tikopians in Polynesia (Kirch and Yen 1982), and the Javanese (Cristanty et al. 1986), among others, employ vertical stratification in their gardens. In these systems, the stratified layers are composed of root and tuber crops below ground, mid sized herbs and shrubs and various sized orchard trees above ground. These systems imitate the surrounding tropical rainforests both in species diversity and in their multi-layered nature. The taro gardens on the Mussau Islands, although less rich in diversity and biomass than these other systems, are also multistoried with their mixture of tuberous root crops, herbaceous growth, small shrubs, papayas, bananas, and *P. tectorius.*

Vertical intercropping has several advantages. By more efficiently using the available space in the garden, soil nutrients and water can be used more effectively and productively (Cristanty et al. 1986; Nations and Nigh 1980). Further, the diversity of cultivars in a single plot also reduces the chance of disease which might affect a monocropping system (Janzen 1973). Kirch and Yen (1982:43) suggest that multi-layering in the Tikopian system either maintains or contributes to soil enrichment, and that on that small island, multiple stories protect against cyclonic effects because the larger canopy trees protect the juveniles in the lower layers (1982:63). The dense canopy and understory also serve to reduce soil erosion (Cristanty et al. 1986).

To what extent these advantages are relevant to Mussau Island arboriculture, or are considered relevant by the Mussau Island tree gardeners, can only be answered by further investigations.

Recent Changes in the Arboriculture Zone

There has been a decline in the importance of tree crops on the islands in the last generation. According to the older members of the community, fruits used to be an essential part of the diet. Today, many of the fruits (e.g., *Terminalia catappa, Syzigium samarangense, S. malaccense*) only are eaten incidentally and then most commonly by children. The consumption of foods which require extensive processing (e.g., *Cycas* and *Pangium* seeds) have disappeared from the diet, and the technique required to make them edible is being lost. Furthermore, the planting of new arboriculture species (except for coconuts, see below) seems to be largely restricted to the older generation. In fact, Ave has complained that many of the children do not even realize that many of the trees in the arboriculture zone are planted.

The introduction of exotic species as well as

general changes in diet have also affected traditional tree cropping. The planting of exotic trees has certainly changed the makeup of the arboriculture zone, although I did not see any evidence that the introduced species were being planted *instead* of indigenous species. The prohibition of betel nut, once a common component in the zone, has also changed the tree garden's composition.

The importance of manihot in the diet has probably had more of an impact on changing the composition of the zone. Since manihot cakes are wrapped in leaves before they are baked, there is great demand for leaves which are suited for this purpose. For instance, *Pandanus dubius* seem to be planted more often today as a supply of leaves than fruit. Certainly, the majority of volunteer trees which are allowed to grow in the zone are left because they provide leaves for baking manihot.

Today, coconut is the primary tree crop planted by younger members of the community. Often fairly large coconut groves are planted. This contrasts to the traditional tree cropping pattern where several tree species are interspersed throughout the zone. The planting of coconuts, almost to the exclusion of other tree crops, is likely related to the fact that processed coconut cream is an essential ingredient in manihot pudding.

Conclusions

The arboriculture zones of the Mussau Islands contain 26 species of indigenous trees which are planted and tended for both food and non-food uses. Some of these species have been cultivated on the islands for over 3000 years. The presence of several distinct varieties within many of these species suggests a long history of selection.

There are several noticeable discrepancies between the archaeobotanical record of the Telepakemalai site and the tree crops used today. The almost complete absence of *Dracontomelon dao* from today's diet as compared to its abundant representation in the archaeobotanical record suggests a dramatic decline in that species' use over time. Conversely, there are several tree crops used today which are not found archaeologically at all. Many of these do not have hard, durable parts which are likely to be preserved in the archaeological record (i.e., *Musa, Syzigium* spp., *Pometia pinnata, Barringtonia* spp., *Artocarpus altilis, Paratocarpus venenosus*). Others (*Areca catechu, Pandanus* spp. other than *P. tectorius* which was recovered archaeologically, *Diospyros peckelii, Terminalia whitmorei* and *Burckella obovata*) have parts which are more likely to be recovered archaeologically. Their absence in the archaeological record may indicate an expansion of arboriculture species over time. Given that our sample comes from a single site, it is unwise to speculate further. As our sample size increases, comparisons of this sort will elucidate our understanding of the development of arboriculture over time.

The arboriculture zones of today are tended gardens. Tree gardeners frequently transplant cuttings or seeds of "better" varieties or new species from other tree crop zones into their own arboriculture zone. Recently, several exotic tree crops have been integrated into the traditional tree cropping system as well. The tree gardener has a mental map of the trees in the zone, and often knows where newly acquired cultivars will be planted beforehand. Most trees are fertilized throughout their growing period, and the entire zone is periodically weeded of unwanted understory vegetation. Trees which volunteer in the arboriculture zone, and are valued for food or non-food uses, are tended along with the cultivars. Both men and women tree garden today, but according to Nevermann (1933), the cultivation of certain species was the exclusive right of a particular sex.

Although a serious competitor for fruit, fruit bats also play an important role in the dispersal of the tree crops. Many of the trees growing in the arboriculture zone grew from seeds dropped by fruit bats. The occurrence of fruit bat dispersed trees is so common there is a local name ("liesa") for a tree, or group of trees, which is started in this manner. A cluster of these trees can be claimed by someone and then tended as if he or she had planted them. Because fruit bats also disperse seeds into the untended forests, bat dispersed species are available for harvesting outside of the arboriculture zone as well.

Without doing a more extensive study, it is difficult to determine the exact role of arboriculture species in the diet. The trees offer readily available staples and more incidental foods at varying times throughout the subsistence cycle. Certain species, such as *Canarium indicum,* which can be stored for extensive periods, and *Spondias* spp., which have long fruiting seasons, are available for consumption for considerable periods of

time. Once planted they require minimum tending, and are thus a good energy investment. Those species which require time consuming processing before being edible are dropping out of the diet today. It is likely that the diverse array of fruits and nuts are an important nutritional supplement to the diet.

Quantification of tree distributions revealed several interesting patterns. Coconut is by far the dominant species in the zone, followed by *Pandanus dubius*, then *P. tectorius*, and finally, *Musa*. Although the dominance of coconut may be somewhat exaggerated because of recent changes in subsistence, I suspect that it was also the most common tree in the past as well. Early ethnohistoric accounts support this notion. Certainly, the tree is highly valued today for several food and non-food uses. Additional censuses on other islands are needed to clarify this.

Although trees in the arboriculture zone as a whole have a random spatial distribution, *Pandanus* spp. are spatially aggregated. The clumping of pandanus may be related to their growth requirements or reproductive ecology.

The tree crop zone is characterized by three distinct vertical strata: a distinct understory layer, a sub-canopy layer composed primarily of mature *Pandanus* spp., and a canopy layer. This contrasts with recent studies of forests of natural origin, where distinct strata are not apparent (e.g., Jacobs 1988; Pompa et al. 1988).

Planters of the tree gardens do take advantage of the distinct heights of different species. *Pandanus* spp. (with the exception of *P. tectorius*), are regularly planted underneath coconuts, the only canopy tree without buttressing or lower branching. The practice of stratified intercropping is a common method in traditional tropical gardens.

There have been major changes in the husbandry and use of tree crops in this century. How well does the tree-cropping system described in this paper represent the time before significant contact with Europeans? Changes which have occurred include the decreased consumption of fruits which require much processing and the decline in consumption of all tree crops in general. The prohibition of betel chewing, and the presumed increased importance of coconut and leaves used to bake manihot, also have had a significant impact on arboriculture. Finally, the decline in the planting of tree crops away from hamlets suggests additional modifications of the traditional system. I was able to minimize the effects of these changes on my results by working with the older members of the community. Still, additional studies involving elders who remember pre-missionary times are needed to clarify these patterns, and examine their generality for other islands.

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Book Review

A Neotropical Companion: An Introduction to the Animals, Plants, and Ecosystems of the New World Tropics. John C. Kricher. Princeton University Press, 41 William Street, Princeton, NJ 08540. 1989. xii + 436 pp. (paper) $17.95. ISBN 0-691-08521-8.

This pocketsized paperback is packed with facts and figures concerning field biology of the American tropics. It truly is a "companion" in that it is a volume that should be packed by students and travelers who are venturing for the first time into the wonderful world of Neotropical biology. At the same time, it serves as an excellent introduction to the New World tropics for armchair naturalists.

A Neotropical Companion is not a lightweight "ecotour" guidebook, however. It is a tightly written and authoritative production for the serious reader by a professor of biology who has a clear talent for clarifying complex topics. A glossary aids beginners, while lists of technical and general references and indices of scientific names and general topics provide more in-depth information for advanced readers.

The book is organized into ten chapters, beginning with general topics (e.g., "Tropical Ecosystems") and progressing to more specific biomes (e.g., "Tropical Savannas") and taxonomic groups (e.g., "Neotropical Birds"). The reader gets advice about tropical travel (e.g., botflies, nasty diseases, and urticating caterpillars) in the early sections, and discussions of speciation, coevolution, and similar conceptual matters later in the book.

Predictably, animals get more coverage than plants, but there is plenty of interest to economic botanists in **A Neotropical Companion**. Some major tropical crops are briefly treated, along with a few paragraphs devoted to swidden agriculture, but there is not really much specific information on economic botany in this book that will be novel to readers of this journal. Rather, there is excellent background and frame-of-reference material on the Neotropics that will be of use to those desiring to become better acquainted with the region's diversity. Chapter 5 ("The Tropical Pharmacy: Plant Drugs and their Consequences") is essential reading for those beginning in the area of tropical economic botany.

This book would be ideal as a supplementary text for undergraduate and graduate courses in economic botany, conservation biology, and tropical ecology. The text is nearly free of typographical errors, and its clear presentation, including line drawings, lively style and broad coverage all combine to make it a good, solid introduction to Neotropical biology.

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