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## LOCAL KNOWLEDGE AND MANAGEMENT OF SAGO PALM (*Metroxylon sagu* ROTTBOELL) DIVERSITY IN SOUTH CENTRAL SERAM, MALUKU, EASTERN INDONESIA

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**ABSTRACT.**—Given the cultural importance of palms it might be assumed that, like other starch staples, they would be internally diverse genetically, yielding large numbers of cultivars reflected in lexical polytypy. This article explores why this does not appear to be so for sago palms (*Metroxylon sagu*), managed by the Nuauulu of Seram, eastern Indonesia. The economic and cultural significance of the sago palm for the Nuauulu, as for much of Maluku and lowland New Guinea, is immense; but the extent to which humans have managed it has been underestimated, it once being widely accepted that reliance on sago was inversely correlated to the development of conventional agriculture. Nuauulu spend about 32 percent of their total subsistence effort engaged in sago extraction. However, given its overall significance as food, in work budgets, as a multi-purpose natural product, and in cultural imagery, the level of formally codified genetic diversity is low. The hypothesis is examined that managed sago palms do not readily lend themselves to the generation of a large number of stable cultivars, and that this is related to modes of reproduction, longevity and single lifetime flowering, and to extensive reliance on vegetative propagation and forms of tenure and husbandry.

**Key words:** *Metroxylon sagu*, eastern Indonesia, genetic diversity, cultural keystone species, local knowledge, crop management.

**RESUMEN.**—Dada la importancia cultural de las palmeras, cabría esperar, que al igual que ocurre con otros productos básicos ricos en fécula, tuvieran una gran diversidad genética, y por ello un gran número de cultivares, lo que debería reflejarse a su vez en una gran diversidad nomenclatural. Este artículo explora por qué esto no ocurre con el sagú (*Metroxylon sagu*), una palmera que manejan los Nuauulu de Seram, en el este de Indonesia. La importancia económica y cultural del sagú es enorme tanto para los Nuauulu, como para los pobladores de las Molucas y de la zona baja de Nueva Guinea. Sin embargo, aunque se acepta ampliamente que la dependencia del sagú es inversamente proporcional al desarrollo de la agricultura convencional, la importancia del manejo de esta planta se ha subestimado. Los Nuauulu dedican aproximadamente un 32 por ciento del total de su esfuerzo de subsistencia a la extracción del sagú. Sin embargo dado su importancia global como alimento, en el presupuesto, como producto natural multiuso, y en el imaginario cultural, el nivel de diversidad genética formalmente codificada es bajo. Se propone la hipótesis de que estas palmeras manejadas no favorecen la aparición de un gran número de cultivares estables. Esto está relacionado con sus modos de producción, su longevidad y el

hecho de que florezca una única vez en toda su vida, y también con la gran dependencia de la propagación vegetativa y de los sistemas de propiedad y de la agricultura.

RÉSUMÉ.—Étant donné l'importance culturelle des palmiers, on pourrait supposer qu'ils présenteraient—à l'instar des autres sources d'amidon—une diversité génétique qui aboutiraient à de nombreux cultivars qu'un lexique polytypique reflèteraient. Aussi, cet article examine en quoi il n'en est pas ainsi pour le sagoutier (*Metroxylon sagu*) que gèrent les Nuaulus du Céram (Indonésie de l'Est). L'importance économique et culturelle du sagoutier pour les Nuaulus, de même que pour une grande part des Moluques et de la basse Nouvelle-Guinée, est immense. Cependant, l'ampleur à laquelle les humains l'ont utilisé a été sous-estimée. Il a déjà été largement admis que la dépendance au sagoutier est inversement corrélée au développement de l'agriculture moderne. Les Nuaulus passent près de 32 pour cent de leur effort de subsistance à extraire le sagou. Toutefois, étant donné sa grande importance en tant que nourriture, le coût lié à son utilisation, ses multiples usages comme produit naturel et en tant qu'image culturelle, la diversité génétique codifiée de façon formelle est faible. L'hypothèse veut que la gestion du sagoutier ne se prête pas à l'établissement d'un grand nombre de cultivars stables. Et que cela repose sur les modes de reproduction, la longévité et la monocarpie (cycle de reproduction unique) de ce palmier ainsi que l'importante dépendance sur la propagation végétative et les formes de gestion et d'exploitation agricoles.

## INTRODUCTION

Palms are amongst the most culturally significant of plants in the way they combine important sources of food with a wide range of other uses (Balick 1988). Their usefulness is often reflected in a prominent symbolic role, and some might appropriately be described as 'ethnobiological keystone species' (Ellen 2001) or 'cultural keystone species'.<sup>1</sup> While recognizing the difficulties of tightly defining this concept and measuring its attributes, there is value in using the term to refer to organisms that by virtue of their usefulness to humans may become ecologically crucial to the maintenance of entire anthropogenic environments, subsistence systems and ways of life. Certainly, 'keystone' is an appropriate characterization of the relationship between the Nuaulu and *Metroxylon sagu* Rottboell (see below), without which the culture and ecology of this local Indonesian population would be barely recognizable. It might also be an appropriate description of some other anthropogenic palm-centered systems such as that focused on *Borassus flabellifer* L. on Roti (Fox 1977).

From their contemporary and historical significance, it is clear that palms have been used by humans for thousands of years, co-evolving with post-Pleistocene populations living in humid tropical and arid semi-tropical regions (Whitmore 1985). We have documentary evidence for the use of palms outside the Mediterranean basin from the early sixteenth century onwards, and for the Mediterranean basin much earlier. The archaeobotanical data are less helpful, though there is palynological evidence of cultivation of *Cocos nucifera* L., *Borassus* L., *Arenca* Labill. from 2500 BP, and less certainly of *Nypa* Steck (Maloney 1994:

147–9). *Metroxylon sagu* was most likely domesticated early in New Guinea, though empirical evidence is elusive. Biogeographic evidence points to its diffusion westwards, at least west of Wallace's line, from its imputed centre of dispersal in Maluku (the Moluccas) and New Guinea, much more recently and perhaps through human activity (Dransfield 1981; Ellen 2004c; Rhoads 1982; Yen 1995).

Given the importance of palms, both in terms of contemporary distribution and historical depth, we might reasonably assume that like other starch staples—rice, maize and potatoes for example—species would be typically internally diverse, yielding large numbers of cultivars reflected in the lexical polytypy of folk classifications (Berlin 1992:106; Geohegan 1976), that is in the many local names given to different types of a culturally significant species. Rice, for example, in individual human populations, may regularly yield between 80 and 100 different local landraces (Iskandar and Ellen 1999:103, 123 n. 2). Indeed, with palm cultigens such as *Bactris gasipaes* Kunth and *Phoenix dactylifera* L., whose fruits are eaten, similar numbers of cultivars may be generated. However, this does not appear to be the case for palms harvested primarily for their starch. The purpose of this paper is to examine whether there are factors in the reproductive biology, ecology and management of starch palms that might influence the systematic and consistent generation, recognition and maintenance of locally-named cultivars. I do so for a particular species, the sago palm (*Metroxylon sagu*), and for a specific human population, the Nuauulu of central Seram in Maluku province, eastern Indonesia (Figure 9).

The economic and cultural significance of *Metroxylon sagu* in the Nuauulu area, as in much of Maluku and lowland New Guinea, is immense; but the extent to which human populations have managed sago has in the past been misunderstood. Indeed, it was once widely accepted that reliance on sago palms was inversely correlated to the development of conventional agriculture. A British Naval intelligence report (NSID 1918:213) notes that gardening is “entirely unmethodical, since the sago palm...requires no care: the natives are remarkably indolent...” (and again, p. 367 “The low standard of agriculture in the Moluccas is due to the prevalence of the sago palm... Agriculture for the production of foodstuffs is little practiced, and in underdeveloped islands like Seram it is quite a subsidiary activity.” Much earlier Forrest (1969 [1779]:42) had declared “No wonder then, if agriculture be neglected in a country where the labor of five men, in felling sago trees...will maintain a hundred” (c.f. Sachse 1907:124). In 1970–1971 Nuauulu spent, on average, 32% of the total time occupied on subsistence activities engaged in the extraction of sago (Ellen 1977, 1988). The time and energy cost of travel when extracting wild sago is substantially greater than, say, fishing or even hunting. Given the overall significance of the sago palm nutritionally, in subsistence-related activity, as a multipurpose natural product, and in Nuauulu cultural imagery, the degree of formally codified genetic diversity appears rather limited. I shall explore why managed sago palms do not appear to readily lend themselves to the generation of a large number of discrete cultivars, and show that this is partly related to modes of reproduction, longevity and single lifetime flowering, and partly to management techniques and the ecology of sago in areas where degree of human interference varies spatially.

More generally, the paper will show how Nuauulu knowledge of *Metroxylon sagu*, its local uses, diversity and properties are organized and embedded in Nuauulu culture. Because of its local economic and cultural significance, its salience in everyday activity, and for an outsider, its intriguingly exotic and complex technology, data on sago palms and their extraction have constituted a perhaps disproportionate part of my field records since 1970, with approximately 122 pages of field notes and 170 photographs. I have deposited documented collections of ethnographic artifacts, either connected with sago production or made from sago materials, in the British Museum (BM), the Rijksmuseum voor Volkenkunde in Leiden (RMV), and the Ethnobiology Laboratory of the University of Kent at Canterbury (UKC). Ellen (2004a) describes the process by which sago is prepared for consumption as food, together with its position in Nuauulu diet, focusing on the significance of the technological process by which it is transformed into food.

At the time that I first embarked on fieldwork amongst the Nuauulu, in 1970, relatively little had been written on the ethnobotany of sago and the subsistence economies for which it is central. Since then we have learned much more about the basic botany of the palm, its uses (particularly as food) and the means by which it is processed throughout its range. This has been possible through the interdisciplinary work of geographers, nutritionists, botanists, agricultural scientists and anthropologists (e.g., Flach 1997; Ruddle et al. 1978; Schuiling 1995; Tan 1977; Ulijaszek 1983).

#### DESCRIPTION OF THE PALM AND ITS DISTRIBUTION

The history of the genus *Metroxylon* and its diagnostic characteristics have been most recently reviewed by Rauwerdink (1986: 165–170; see also Flach 1997). *Metroxylon sagu* is an arborescent, clustering (multi-stemmed), monoecious palm, often with a more or less spiny columnar stem or trunk, 7–9 m high, 15–20 cm diameter near the base, and leaves up to 7 m long in mature specimens (Figure 1, Figure 2). It has an enormous inflorescence, which appears at the end of the life of a palm through the bolting of the main axis (stem) of the trunk and the growth of numerous lateral inflorescences. *Metroxylon sagu* flowers occur in pairs (dyads) throughout the spikes, each comprising a staminate and similar hermaphrodite flower. The fruit epicarp is covered in vertical rows of reflexed scales. It has pinnate leaves and the petioles have a leaf sheath clasping the stem, which arises as a complete cylinder and which later splits on the opposite side to the petiole. The basic chromosome number is 13, which separates *Metroxylon* from most other Calamoid palms, the section of the palm family that contains rattans and other useful species. Sago is the starch extracted from the stems where it has been stored as the excess of vegetative growth preparatory to the hapaxanthic (once in a lifetime) flowering. The stout trunks take about 15 years to reach the flowering stage. However, palms also reproduce vegetatively by freely sending out rapidly-spreading basal stoloniferous suckers from massive rhizomes. It is a combination of the high starch content of the trunk and the suckering mode of vegetative reproduction of trunks that has made sago palms important to humans.



FIGURE 1.—Architecture of *Metroxylon sagu*, showing hapaxanthic axes. Following Uhl and Dransfield (1987:Figure 5.5).

Like some other types of palm, *Metroxylon sagu* has been subject to “historical overdescription” (Dransfield 1999:7), with local sub-specific taxa being accorded specific status. The recent trend in the taxonomy of the species has, therefore, been generally one of simplification and lumping. Rumphius, in his *Herbarium Amboinense* (1741:Liber 1, Chapter XVII:75–76), describes four species of sago

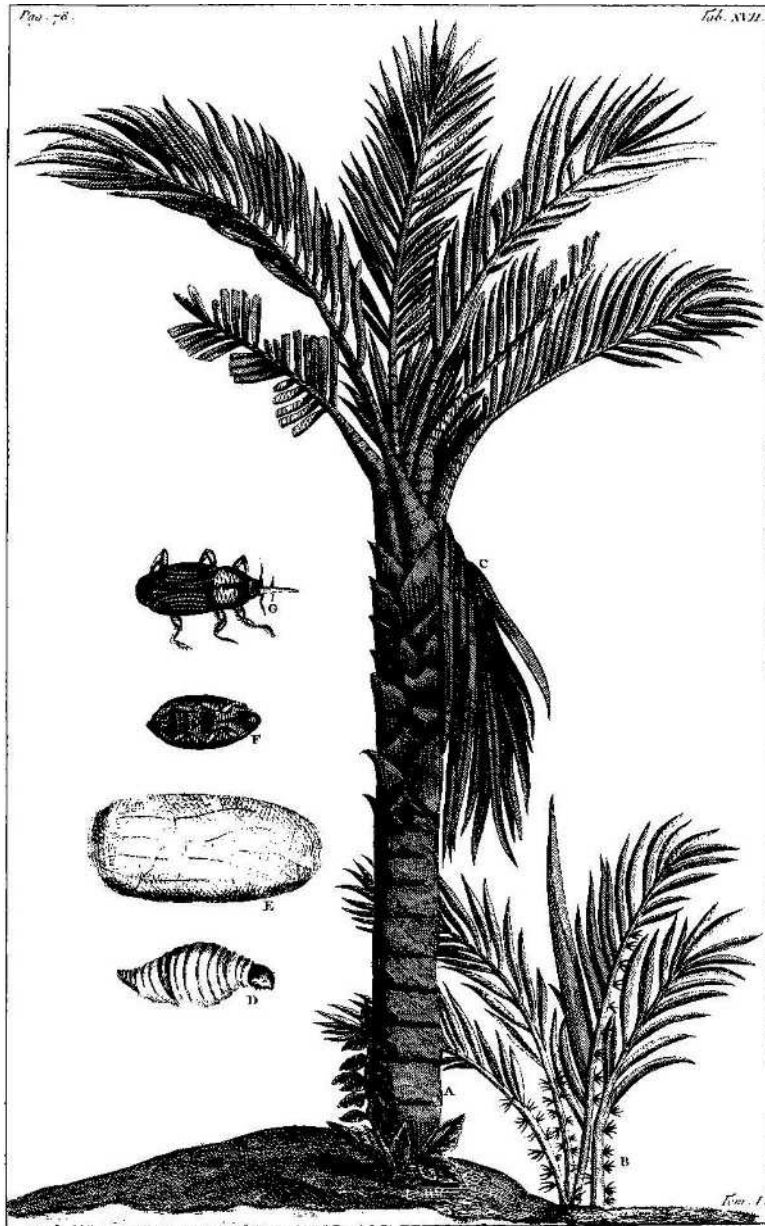


FIGURE 2.—Black and white reproduction of an originally colored plate from the *Herbarium Amboinense* of Rumphius (Liber I, Tab. xvii). The engraving represents a sterile sago palm with the adult, larva, pupa and pupal case of the Sago Palm Weevil, *Rynchophorus ferrugineus* var. *papuensis*.

palm in Ambon that he places in the genus *Sagus*: *genuina* (includes *duri-rottang*), *silvestris*, *longispina* and *laevis*. Until recently it has been conventional to distinguish two closely-related species of *Metroxylon*: *M. sagus* with smooth leaf sheaths and *M. rumphii* with spiny leaf sheaths (Corner 1966:310). However,

Beccari (1918) noted that the two are barely distinct. The fact that the fruits of *M. rumphii* and *M. sagu* give rise to seedlings of both spiny and spineless types has led to the status of *M. rumphii* being called into question (Jumelle 1925:22), and the view that spines, though highly salient, are probably of little diagnostic value from the point of view of botanical taxonomy since all gradations of spinescence are found (Barrau 1958:3; 1959; Kiew 1977:151; Lea 1964; Sastrapradja and Mogeia 1977:112). Flach (1977:159), on the basis of *ex situ* experimental work, and Rauwerdink (1986:178), on the basis of systematic field observations, have confirmed that spiny sago palms can produce both spiny and spineless seedlings from a single inflorescence. As a result, *Metroxylon sagu/rumphii* has been reduced to one species (*M. sagu* Rottboell).

Within the species, Rauwerdink (1986:168) identifies four subspecies (formae), reflecting slightly different phenotypes rather than two or more different species or subspecies. He pays particular attention to spine variability, noting that crown leaves of a mature specimen usually have shorter spines than those on leaves from offshoots of the same stand, that leaf sheath spines are larger than petiole and rachis spines, and that spine length appears to be governed by a simple genetic mechanism. Of course, with vegetative reproduction, phenotypic characters such as these can be transmitted from old to new plants over considerable spatial distances and maintained over long periods of time, while variation induced by sexual reproduction from seeds may lead to the expression of hitherto recessive traits. Spinescence, therefore, as a morphological character, has moved from being seen as highly salient diagnostically at the species level (Rumphius), to being seen as of little diagnostic value at all (Barrau, Beccari, Corner), to being of some diagnostic value at the sub-specific level (Rauwerdink). As we shall see, spines remain important as a character by which Nuaulu distinguish landraces, and in this respect it might be said that we have come full circle, since the Rumphian observations were themselves derived from the botanical knowledge of his local Ambonese assistants.

The present-day geographic distribution of *Metroxylon sagu* is illustrated in Figure 3. It is found from southern Thailand and Burma in the west, through the Malaysian peninsula, throughout most of the wetter parts of the Indonesian archipelago, the southern Philippines, the island of New Guinea and as far east as the Solomon islands. Of those areas of Indonesia (outside of New Guinea) where the palm is found and its pith, crown and woody parts used as food and other products, the most important is undoubtedly Maluku. *M. sagu* is found and used all over north and central Maluku, though it is less important in the southeast (Kei and Tanimbar), with the exception of Aru. It is almost entirely absent in the southwest (Wetar, Babar, Roma, Damar). In the core areas—especially on large islands—it occurs mainly, though not entirely, in lowland swamp forest. Beccari (1918:157) suggests that what is now accepted as *Metroxylon sagu* had a centre of origin in Maluku (especially Seram), though more recent authorities favor New Guinea (Barrau 1959; Flach 1997:21). We can at least claim that in palaeobiogeographic terms, both the genus and the species evolved in Sahul rather than Sunda, that is east of Wallace's Line, which separates a predominantly Australo-Pacific flora from a predominantly Oriental flora. However, that it is now often the dominant species in such areas, and is



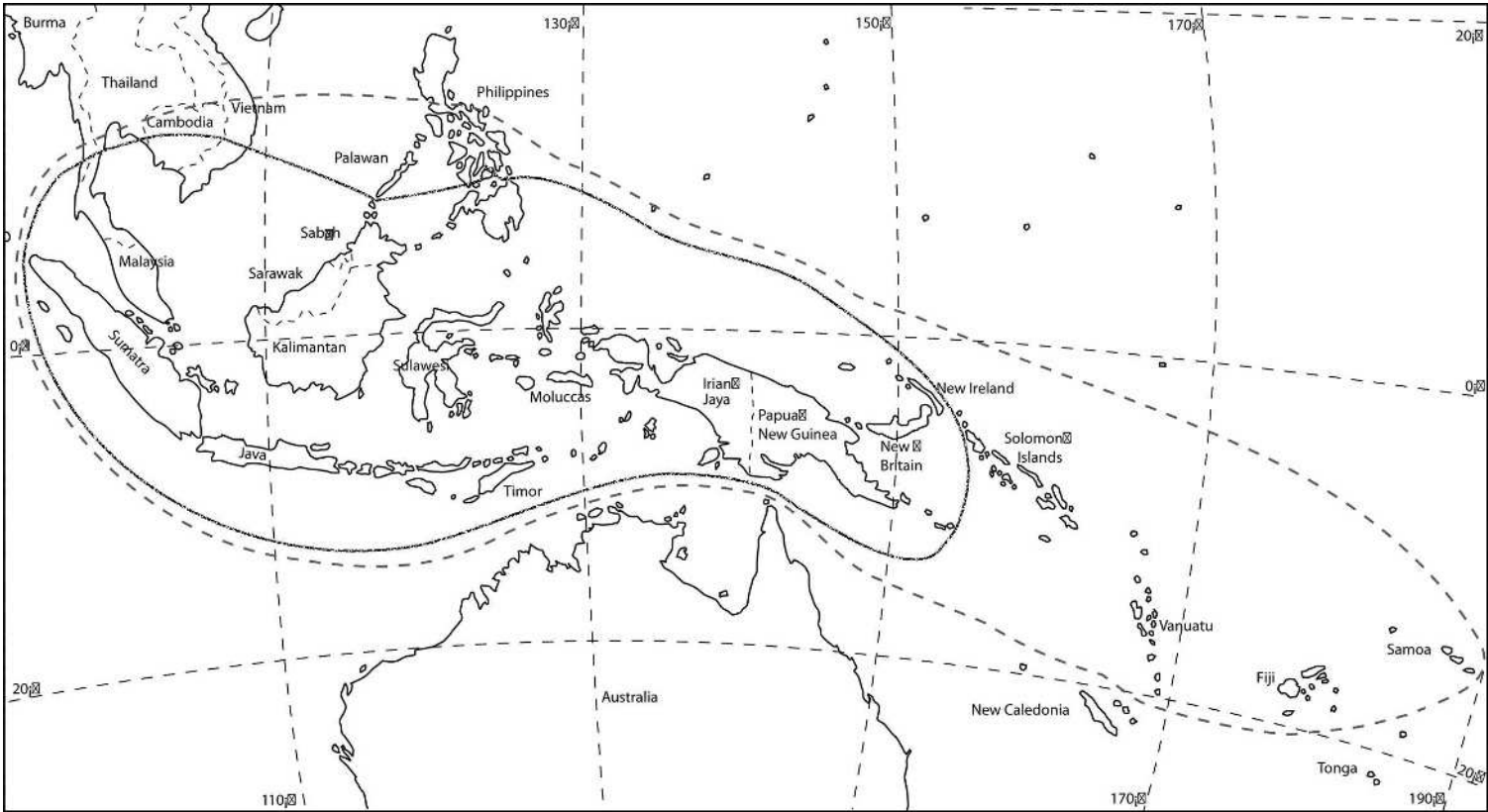


FIGURE 3.—Present-day geographic distribution of *Metroxylon sagu*. The outer line indicates the extent of the genus *Metroxylon*, and the inner line the extent of the species *sagu*. This distribution incorporates areas where *M. sagu* has been introduced through human agency, and the strictly 'natural' distribution of the genus is generally regarded as reaching its westerly limit with New Guinea and parts of the Moluccas.

found on both sides of Wallace's line, suggest a role for human activity in its dispersal. Historically, the earliest Western reports are found in Marco Polo (*The Travels*, 1958:257).

#### NUAULU KNOWLEDGE OF SAGO PALM MORPHOLOGY AND GROWTH

The Nuauulu term *hatane* unambiguously corresponds to a folk category that matches the taxon *Metroxylon sagu*. This palm is the Nuauulu's best known and most culturally salient plant species, judging from its uses, role in ritual and other symbolic references. Its position as an ethnobiological keystone species influences its classification by the Nuauulu. In many ways it might seem to belong firmly in the life-form category *ai*, tree. However, it does not closely resemble the focal definition of tree in Nuauulu plant semantics, because it has no branches, hard trunk wood, or woody root system, and because it grows rapidly for 15 years and then flowers, fruits and dies. The difficulties the Nuauulu have in placing the category *hatane* in the life-form *ai* are repeated for the classification of other palms by the Nuauulu, and also more generally in the folk classifications of tropical palm-using peoples (Ellen 1998a). One kind of sago, *hata ai*, is so labeled because the absence of spines makes it more closely resemble focal *ai*. In these characteristics sago is allied to many other palms, most obviously soft-centered palms, which are more accurately viewed as a kind of plant, without any intermediate life-form. In this respect, the folk classification of palms reflects one tradition in scientific botany that conventionally excludes all monocotyledons from the habit 'tree'.

But while sago is not a tree in Nuauulu terms, neither is it unambiguously classified as a 'palm'. As in many languages of the tropical belt where palm species abound, there is no single encompassing term for palms, though various palms may be seen to be related by degrees of covert family resemblance (Ellen 1998a). Nuauulu note the similarities between *Metroxylon sagu* and other palms that produce edible flour and that are soft-centered palms; which they contrast with hardwood palms valuable for manufacturing, for example, bows and arrow mid-shafts (e.g., *Oncosperma tigillarum* (Jack) Ridley). The spinescence of most phenotypes of *Metroxylon sagu* invites linkage with rattans (*meute*). Beyond the direct assertions of similarity made by individual informants, we can detect evidence for shared acceptance of certain covert resemblances between *M. sagu* and other palms in the vocabulary of plant parts employed (Table 1). Thus the term for a sago flower (*usue*), is used for other palms (and some other plants, such as banana), but not for the flowers of herbs.

Table 2 lists the stages of sago palm growth as recognized by Nuauulu. A palm must be cut before inflorescence formation has begun to drain away accumulated stem starch. During the span of inflorescence growth, the palm will be preferentially cut as the first branches begin to appear, if the maximum yield is to be obtained; when it is, as they say, 'pregnant'. Failing that, the palm will be cut just before the inflorescence emerges (usually determined by the shape of the apical tip), and failing that when it is fruiting. After this, the starch will rapidly deteriorate. In practice, however, many sago stands are cut long before the inflorescence has appeared; but never before eight years or after fruiting

TABLE 1.—Nuauulu vocabulary of *Metroxylon sagu* paronyms.

Nuauulu term	Gloss
Leaves:	
<i>hatane totu mene</i>	dead, "dry" lamina
<i>totu mataea</i>	young, "unripe" lamina
<i>hatan totue</i>	leaflet or pinna
<i>hatan kaie</i>	upper rachis
<i>hatan(e) asite</i>	stem of pinnate leaf
<i>ainatai</i>	sago thatch, sago canopy
<i>tope</i>	woody petiole and rachis
<i>kainuni</i>	spine
<i>kinohae</i>	leaf sheath
<i>kinohae anoi</i>	fibrous inside of leaf sheath
<i>makuhasite</i>	hardened outer part of basal leaf sheath - used for making containers
Reproductive parts:	
<i>hatan usue</i>	flower
<i>hatan ukune</i>	apical tip
<i>sanae</i>	main branch of inflorescence and infructescence
<i>kam matae</i>	stalk on which fruits grow (lit. 'unripe betel pepper fruit', indicating the resemblance)
<i>hatane huae</i>	fruit
Stem:	
<i>mpiae</i>	sago flour
<i>mpiae isie</i>	pith inside sago stand
<i>eau</i>	pounded sago pith
<i>hata ninate</i>	contents of a sago tree
<i>hatan tuete</i>	stump, tends to be much wetter than rest of tree
<i>hata notoi</i>	empty stump
<i>han tinaie, aikune</i>	stem, trunk, stand
<i>hatan anae</i>	basal sucker
<i>hata matae, mata hatane</i>	sago clump
Roots:	
<i>namte</i>	roots
<i>tonote</i>	small adventitious roots

TABLE 2.—Nuauulu terms for *Metroxylon sagu* growth stages.

Nuauulu term	Gloss
<i>hatan anae</i>	young stand thrown out by basal suckers: 1–2 years
<i>hata sane</i>	younger stand but not ready for extraction, beginning of trunk formation: 3–5 years
<i>hata(e) nam tuae</i>	stand ready for extraction: 6–14 years
<i>hata nene usue rehokai,</i> <i>hatane nene noine</i>	palm in flower
<i>hata huae</i>	sago palm in fruit
<i>hata mene</i>	old, "dry," stands of sago that have flowered and died

(approximately 15 years in most Nuauulu locations). Flach (1977) indicates that harvesting takes places between eight and 12 years for plants grown in mineral soils (inseptsols) and 15 to 17 years for plants grown in peaty soils (histosols). Stands of sago that have flowered, fruited and died (*hata menai*), whose starch has deteriorated, are said by Nuauulu to be 'dry'. The tall stands that have dropped their crown leaves appear like ghostly factory chimneys through the canopy of the swamp forest. From time to time one hears a cracking and crashing in the forest as rotten stands fall.

Nuauulu are expert at estimating age of a tree and quality of the starch, by making borings and tasting the pith. Hard and bitter (as opposed to tough) pith is preferred over sweet soft pith, which indicates that the process of oxidation has already set in, whether for unprocessed pith in the living stand or in the processed pith. During its lifetime the signs of healthy sago are a mass of dark green foliage, prolific suckering, and a long rhizomatous (horizontal and rooting) part of the stem. The palm is subject to pests, and destruction of the apical meristem makes it particularly vulnerable to predator attack. However, compared with other annual and tree crops it is hardy and resistant. This is an important consideration in explaining the overall significance of sago as a stable long-term source of food in the spectrum of subsistence techniques. Wild pig will eat the pith of damaged or deliberately felled palms, termites congregate and nest (*tanane ne numa*) on the palm in the wet season, and various other insects use it as a host: borers, hispid beetle larvae, skipper butterfly larvae, bag worms, and Rhinoceros Beetle (*Oryctes rhinoceros*). None of these cause significant harm to the tree, and in villages may be kept in check by chickens and other livestock. However, the most ecologically and culturally significant insect predator is the Sago Palm Weevil (*Rhynchophorus ferrugineus*, possibly also *R. bilineatus*), the eggs of which are laid in the decaying stump or trunk, in lesions in the living stand, in heaps of waste pith, in stored flour, or in the soft tissue of a sago palm leaf sheath. The grubs (*eti hatane*) are harvested by Nuauulu as a significant protein source (Ellen 1993b:163, 173–174).

#### NUAULU SAGO LANDRACES

The category *hatane* is partitioned by Nuauulu into a maximum of 11 categories, which are not further routinely sub-divided, each labeled by a discrete lexeme, employing either a binomial nomenclature (e.g., *hata ai*, *hata umena*) or a trinomial nomenclature (e.g., *hata nuni sekane*, *hata nun metene*). Some lexemes are ambiguously trinomial/binomial where one contracted morphemic segment elides into another (*hata nuni metene* > *hata numetene*). In some cases there is evidence for 'true' synonyms; in other cases there is evidence of lexical variance without true semantic synonymy, best explained as ideolectal, dialectal or contextual cognates of the same basic lexeme. Thus, when applied to the same plant, *hata ai* and *hata warata* are quite independent names semantically; whereas *hata nuni sekane* and *hatane sekane* are clearly lexical variations of the same term, but both equally acceptable.

As in Nuauulu ethnobiological classification generally, when adjectival qualifiers are added to create binomials, it is usual to delete the final syllable

TABLE 3.—Nuaulu terms applied to recognized landraces of *Metroxylon sagu*.

Nuaulu name	Lexical variants	Literal gloss	Ambonese Malay	Database File No.
<i>hata nuni mane</i>		<i>nuni</i> = spine (throughout), <i>mane</i> = soft		737
<i>hata nuni nasinana</i>	<i>hatane nun nasinanae</i>	<i>nasi</i> = blood, <i>nanae</i> = delicious		739
<i>hata nuni uakane</i>				771
<i>hata ai</i>	<i>ai warata, hata kaiohatai</i>	<i>ai</i> = tree, <i>warata</i> = Dutch	sagu molat	738, 518
<i>hata(ne) umena</i>	<i>hata m(u)ena</i>		sagu putih	520
<i>hata napaune</i>	<i>hatane anapaune, hata nuni anapaune</i>			519, 740
<i>hata nuni metene</i>	<i>hatane numetene</i>	<i>metene</i> = black		524
<i>hata nuni tamnone</i>	<i>hatane nun tamnone</i>	<i>tamnone</i> = Tamilau (see Figure 3)		526
<i>hata nuni msinae</i>	<i>hatane nuni msinae</i>	<i>msinae</i> = red	sagu merah	522
<i>hata nuni ueri</i>	<i>hatane numuari</i>			525
<i>hata nuni sekane</i>	<i>hatane sekane</i>	<i>seka</i> = clean		522

of the uninomial to be qualified (in this case *hatane* > *hata*) to generate binomials such as *hata sekane*. Occasionally, a binomial is generated without contraction, as in *hatane ai*. Segments in addition to the initial segment in polynomials may also be sometimes contracted (e.g., *nuni* > *nun* > *nu* > *u*; *umena* > *mena*; *anapaune* > *napaune*). This gives scope for considerable lexical variation, usually in response to economy in sentence structure. I have listed some of the more common variants along with synonyms in column 2 of Table 3. The terms listed in column 1 of the same table are those variants that I most frequently heard, said by some informants to be the preferred or 'correct' terms, and it is these that I standardize as the labels for landraces in the following discussion on knowledge of genetic diversity. I use the word *landrace* (following Shigeta 1996:235; see also Brush 1991:154–155), to distinguish Nuaulu categories for sub-divisions of ancestral crop species from 'varieties' in the conventional Western taxonomic sense, or 'cultivars' in the strict agronomic sense. Thus, in this context a landrace is a local category for grouping cultivated or managed sago plants according to common characteristics reflected in specific vernacular names. Landraces represent locally distinguished types of germplasm developed by local people, in contrast to 'varieties', which are usually the products of institutional breeding.

Nine of the 11 terms include the morphemic segment *nuni* or its contraction, and one other (*hata umena*) may also include a vestigial trace of the same morpheme (*u*). *Nuni* is 'thorn' or 'spine', suggesting that within the primary category *hatane*, an intermediate category separating out spiny types of sago is distinguished. Indeed, the term *hata kainuni* is frequently elicited, while only one term (*hata apane*) refers definitely to a spiny type without being lexically so designated. This leaves just one category, labeled *hata ai*, which does not refer to kinds of sago with spines. Having said this, however, I believe the intermediate category labeled *hata kainuni* is only weakly stressed in Nuaulu classification of sago types, people most usually referring directly to the terminal type.

TABLE 4.—Distinguishing characteristics of labeled Nuauulu categories for *Metroxylon sagu* landraces.

Nuauulu name	Spinescence	Flesh	Other features <sup>1</sup>	Voucher <sup>2</sup>	Figure
<i>hata nuni mane</i>	moderately short spines in continuous parallel transverse ridges or series	very soft flesh	light bark, color as <i>h. nasinana</i> ; leaf crisp, leaf sheaths clinging	Kew 96-160 96-15-31 96-15-32 96-13-26a	4a, 4b
<i>hata nuni nasinana</i>	moderate to long spines in continuous parallel transverse ridges or series	red flesh	light bark, leaf sheaths clinging, otherwise same as <i>h. nuni weri</i>	96-15-05 96-15-06 96-13-28 96-13-29	4c, 4d
<i>hata nuni uakane</i>	fine spines in continuous parallel transverse ridges or series		leaf sheaths clinging	96-15-34 96-15-35	5a, 5b
<i>hata ai</i>	spineless	very white flesh	reproduces both vegetatively and sexually, cut of preference in Somau; girth=160	96-08-23	5c
<i>hata (ne) umena</i>	short spines in broken horizontal groups	fresh clean and white, almost as <i>hata ai</i>	leaf sheaths do not drop off cleanly, thus much surface moisture is retained; thin rough surface with much moss growth; requires more work for same yield, girth=123, bark=1.5, thicker than <i>h. sekane</i>	96-02-22 96-02-25 96-04-30	5d, 5e, 8c
<i>hata napaume</i>	spines	reddish flesh	leaf sheaths drop off cleanly, smooth bark (1–1.5), girth=138; otherwise almost same as <i>h. ai</i>	96-07-13 96-14-09	
<i>hata nuni metene</i>	black spines in continuous parallel transverse ridges or series across leaf sheath; spine clusters webbed at base		dark bark, leaf sheaths not clinging	96-14-12 96-14-13	6a, 6b

TABLE 4.—Continued.

Nuauulu name	Spinescence	Flesh	Other features <sup>1</sup>	Voucher <sup>2</sup>	Figure
<i>hata nuni tamnone</i>	short, fine and hard spines in almost continuous parallel transverse ridges or series		girth=204, bark=1–1.5	96-02-23 96-02-24 96-02-25 96-04-29a	6c, 6d
<i>hata nuni msinae</i>	clusters of long hard spines with red blotches at base; some spines 22 cm	white flesh	leaf sheaths moderately clinging, girth=155, bark=2	96-04-28 96-04-35 96-13-04 96-13-05	7a, 7b
<i>hata nuni weri</i>	numerous long fine spines in continuous parallel transverse ridges or series	dirty flesh	leaf sheaths clinging, not as large as other cultivars but grows quickly (7–9 years), girth=126 (flowering), good taste; bark=1	96-04-29b 96-14-07 96-14-08	7c, 7d, 8d
<i>hata nuni sekane</i>	small numbers of moderate spines in continuous parallel transverse ridges or series; spines on young; petiole orange, short and thick		leaf sheaths variably clinging; bark=1, thinner than <i>h. umena</i> , light color	96-15-36 96-16-01 96-16-02	8a, 8b, 8e

<sup>1</sup> All measurements in centimeters.<sup>2</sup> All codes refer to photographs held in UKC Ethnobiology Lab collection, except Kew 96-160, which refers to the field number of an herbarium specimen held at the Royal Botanic Gardens Kew.

It is now accepted (Flach 1997:33; Schuiling 1995) that when local people consistently report regular differences between sago types then this must be taken seriously. The details elicited from Nuauulu informants, and confirmed by me through direct personal observation and photography are set out in Tables 3 and 4, and Figures 4 to 8. Unfortunately, I was unable to collect data on sago landraces using the excellent guidelines and questionnaire devised by Schuiling. As Schuiling himself admits, local informants often find it difficult to 'list characteristics' and seem to rely on general appearance, in a way that often defies quantification (1995:45). In other words, in the language of cognitive anthropology, their classificatory model is less based on 'distinctive features' than on categories with fuzzy boundaries and cognitive prototypes (Ellen 1993a:72–75). The main folk attributes which people use to distinguish landraces are morphological, in particular characteristics relating to spinescence. Other characteristics, such as the rate of maturation (that is variation in life-span) or quality of the pith, are important, but appear to be secondary. Leaf form (as relevant to thatching) and shoot quality (in relation to their edibility) were not mentioned by informants. There is no evidence for a 'residual' category (Ellen 1993a:82–83) of un-named spontaneous variants not easily fitting in elsewhere, such as the 'khalt' (mixture) category, which Gary Martin (personal communication) reports for Arabic and Amazigh folk classifications of date palms in Morocco, and which corresponds to dates produced by offspring of sexual reproduction. Instead, most Nuauulu sago categories appear to be used in a way that accommodates the variation which might be introduced in this way.

In some important respects Nuauulu regard all named sago landraces as of equal quality and utility. As food, the starch of all is said to be similar, each yielding about the same amount of flesh when mature. Because the consumable part—the starch from the interior of the trunk—is more limited in its potential morphological diversity and because desirable qualities are more difficult to select for than, say, potato tubers, date palm fruits or rice grains, may partly explain why diversity is not as extensively labeled as in these crops. External characteristics would need to be selected for that correspond in a predictable way with starch quality in a manner similar to that suggested by Boster (1984) for manioc. Some Nuauulu claim that spiny landraces produce stickier paste, though no one claimed that spine characteristics might be a good predictor of starch yield. Although this is what Nuauulu say, and we must therefore conclude that for them any variation in flesh productivity between landraces is not significant for their purposes, Ehara et al. (2000) report that variation in pith dry-matter yield is correlated to trunk diameter and dry-matter percentage of pith, and that trunk diameter reflects genetic variation and growth conditions rather than growth period. Pith dry-matter yield, they report, is highest in short-spine types, followed by spineless and long spine types.

Nuauulu do, however, finely appreciate the quality of individual trees below the level of distinguished landraces. Thus, newly cut pith taken from a tree immediately after it has been felled should be hard rather than tough (indicating a high concentration of starch to fiber), and bitter as opposed to sweet. Nuauulu also say that different named kinds of sago palm grow to equal mature heights, though they do recognize trunk diameter as a variable, and also growth rate.



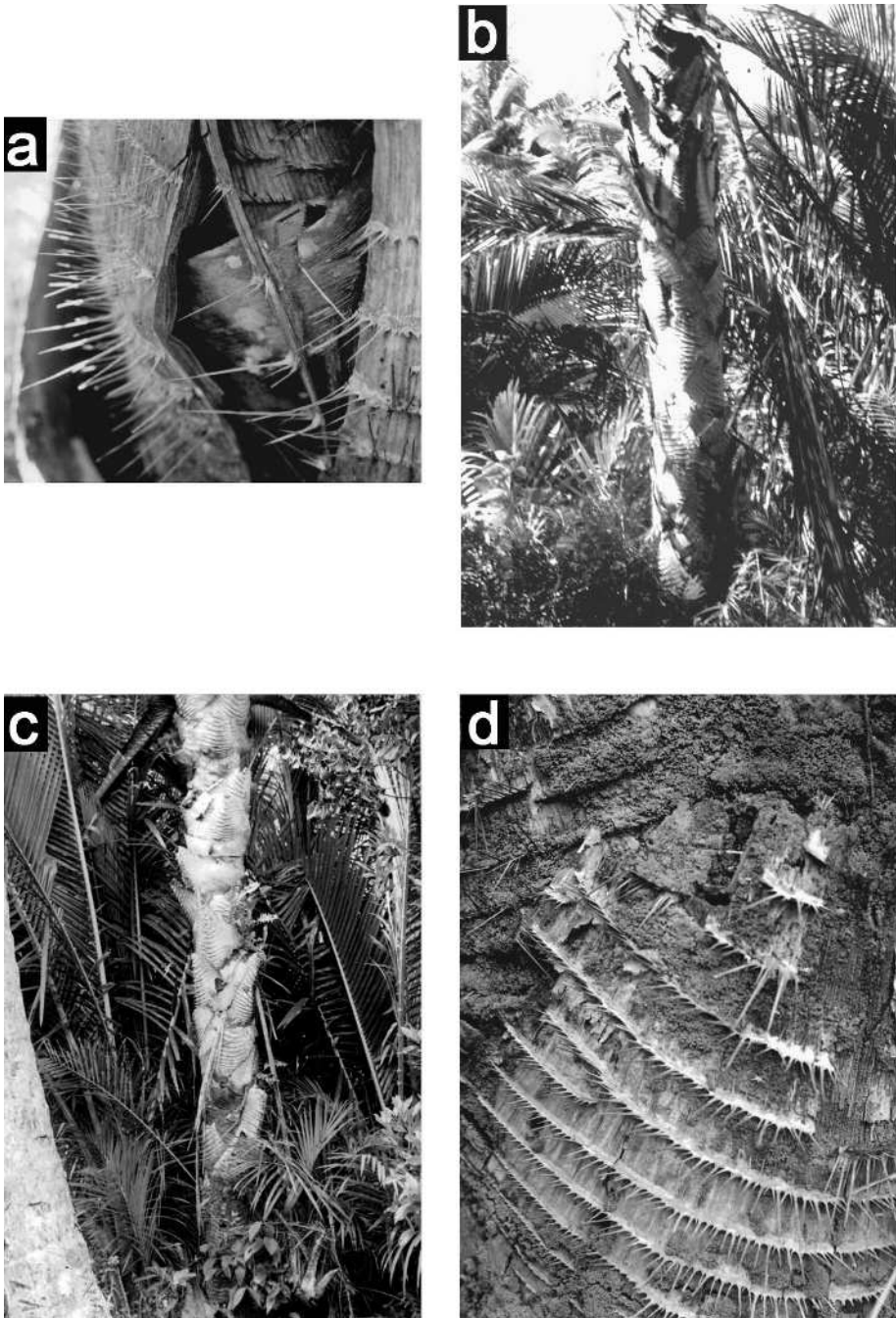


FIGURE 4.—*Hata nuni mane* landrace, detail of spine pattern (a) and trunk (b), compared with *hata nuni nasinana*, trunk (c) and detail of spine pattern (d). Photographs by Roy Ellen.



FIGURE 5.—*Hata nuni uakane* landrace, detail of spine pattern (a) and trunk (b), compared with *hata ai* (c) and *hata umena*, detail of spine pattern (d) and trunk (e). Figure 5 continued on the following page. Photographs by Roy Ellen.



FIGURE 5.—Continued.

Thus, several informants in Rohua preferred to plant *hata nuni weri*, which is not quite as productive as other sago landraces, and has flesh with a dirty appearance, but grows quickly (seven to nine years) and has a good taste. This latter was stated by several informants as being significant, and this is consistent with the observation by Ehara et al. (2000:202) that variation in growth period to harvest is an important characteristic identifying landraces and different growing sites.

Nuauulu informants provided some data on planting preferences with respect to different labeled landraces, and we have some survey evidence of the frequency of different landraces in different areas and of differential harvesting. Table 5 shows the distribution of Nuauulu-labeled landraces for seven sites surveyed during 1996, in each of seven watercourse systems. These watercourse systems provide toponyms for Nuauulu resource areas that are indicated in Figure 9. In Table 5 the sites are ordered in terms of their distance from the village of Rohua, the village that owns these sites, and extracts sago and other plant resources from them. In each site a rapid count was made of mature stands of recognized landraces, all of which appear to be labeled in some form. For the purpose of the survey a 'mature' stand was reckoned to be any stand that was four meters or more in height. The entry of a plus sign (+) in the table indicates that five or more stands were observed in each site; the entry of a minus sign (–) indicates that no stands of a particular landrace were observed. Using this method, no entries are registered for *napaune*. *Umena* was the most frequent, present in four out of seven sites; and *nuni weri*, *metene*, *uakane* and *nuni mane* were recorded as present in one site only.

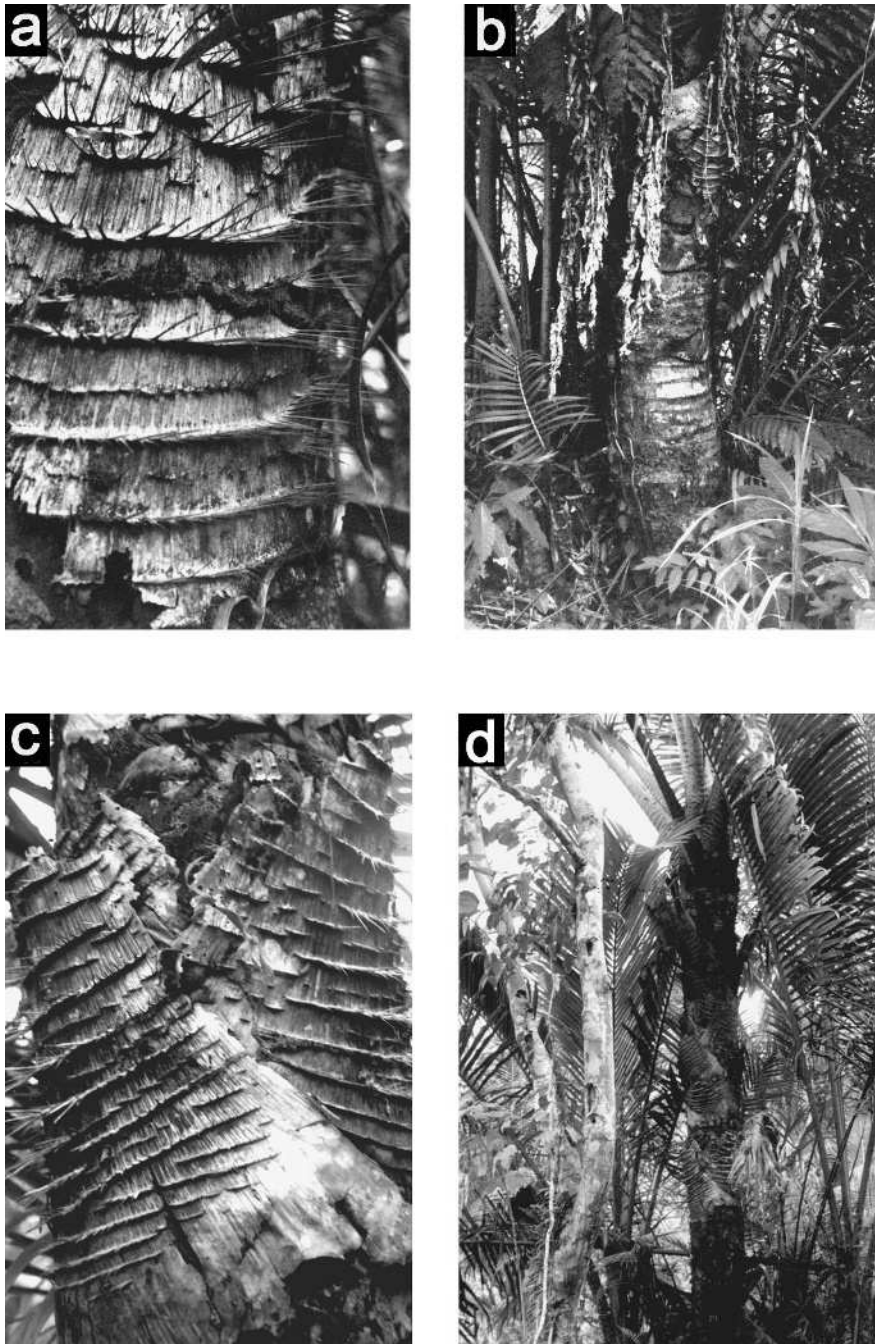


FIGURE 6.—*Hata metene* landrace, detail of spine pattern (a) and trunk (b), compared with *hata tamnone*, detail of spine pattern (c) and trunk (d). Photographs by Roy Ellen.

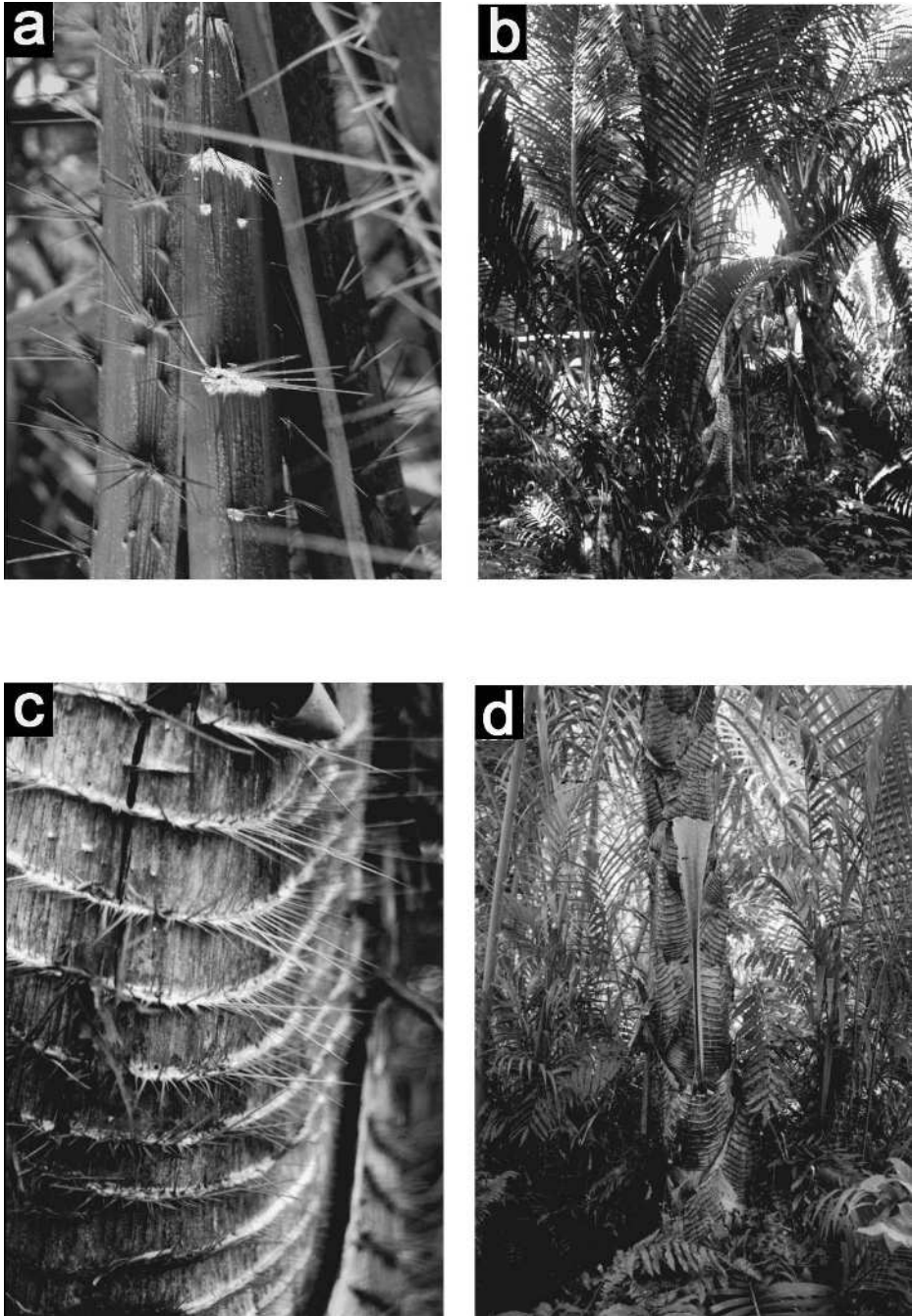


FIGURE 7.—*Hata msinae* landrace, detail of spine pattern (a) and trunk (b), compared with *hata nuni weri*, detail of spine pattern (c) and trunk (d). The red blotches at the base of the spine of *hata msinae* (a), visible in the color version of the photograph, are represented as white in this image for emphasis. Photographs by Roy Ellen.

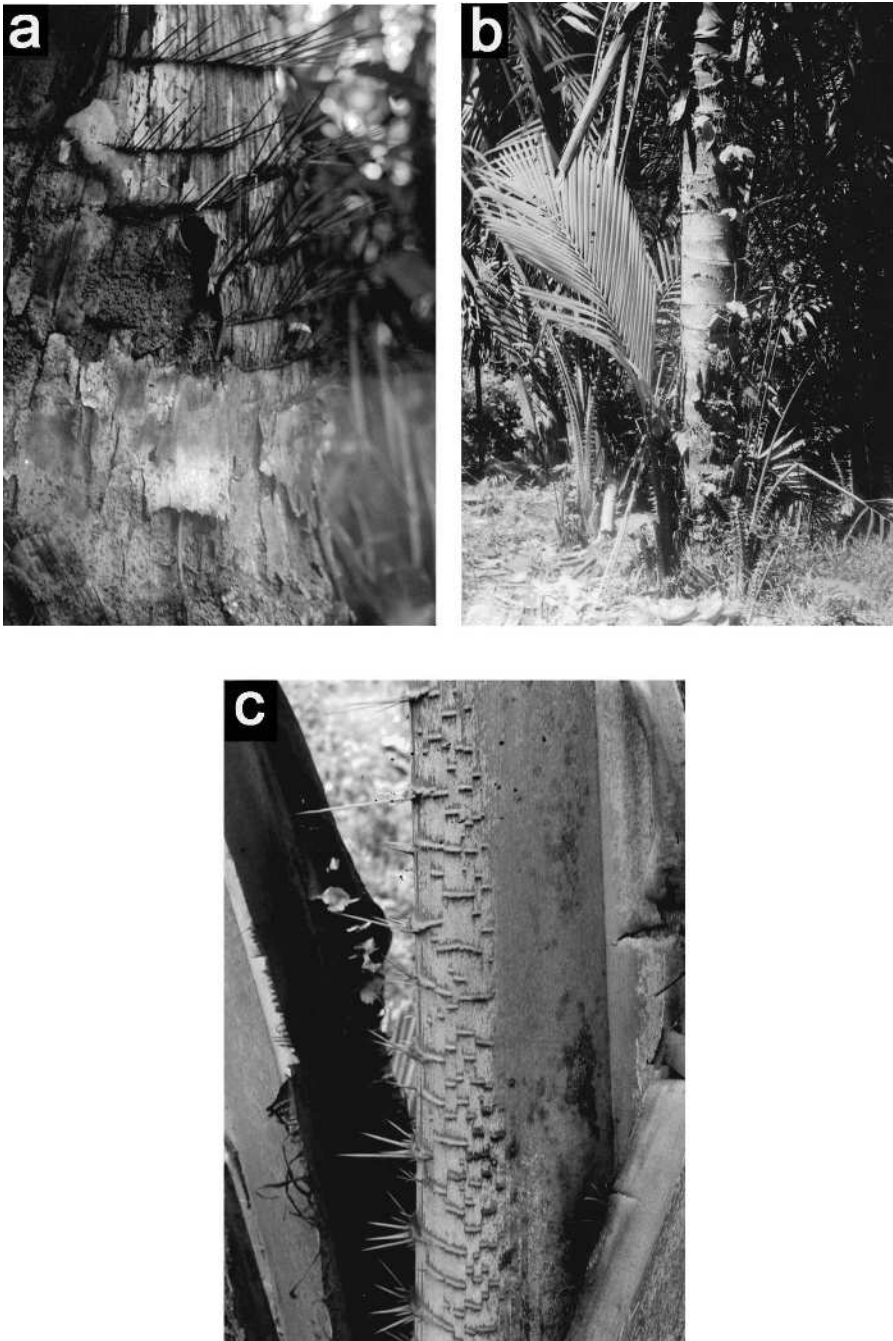


FIGURE 8.—*Hata sekane* landrace, detail of spine pattern (a) and trunk (b). Comparison of spine arrangements on young petioles of *hata umena* (c), *hata nuni weri* (d) and *hata sekane* (e). Photographs by Roy Ellen.



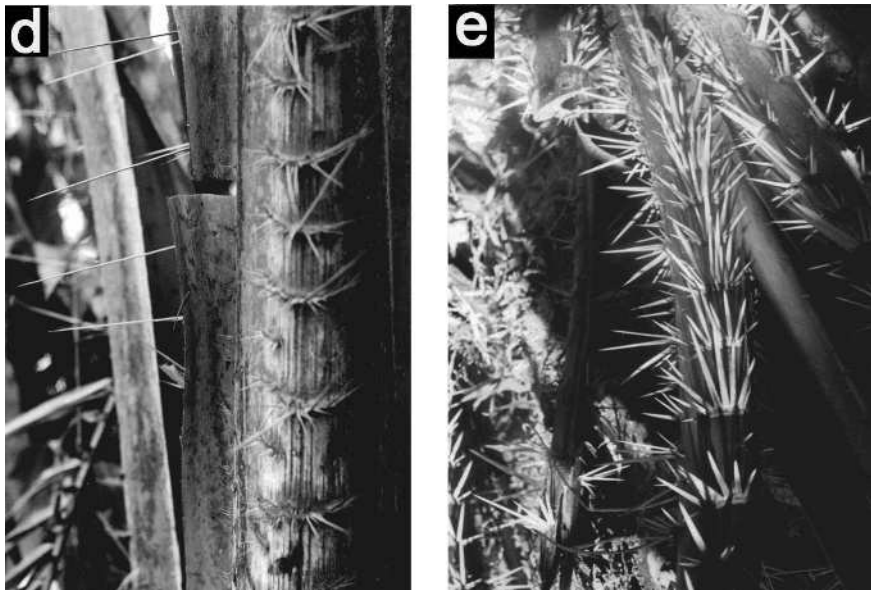


FIGURE 8.—Continued.

Sites nearer the village presented a more varied combination of landraces than sites further away. This picture is all the more pronounced when it is noted that the five nearest sites to Rohua were all less than five kilometers distant, whereas the two furthest were between 10 and 18 kilometers. I suggest that this pattern reflects a partially deliberate and partially inadvertent diversification strategy in sites nearer the village, where there are also greater opportunities for germplasm to be redistributed among social groups. Certainly, individuals purposefully seek to increase variety of the stock of sago palms accessible to them

TABLE 5.—Distribution of Nuaulu labeled landraces in seven sites in named resource areas at varying distances from village of Rohua.

	Rohua	Yoko	Near Upa	Far Upa	Makoihiru	Yala	Somau	Number of sites
<i>hata nuni mane</i>	—	+	—	—	—	—	—	1
<i>hata nuni nasinane</i>	—	+	—	+	—	—	—	2
<i>hata nuni uakane</i>	—	+	—	—	—	—	—	1
<i>hata ai</i>	—	+	—	—	—	—	+	2
<i>hata umena</i>	+	—	—	+	+	—	—	3
<i>hata napaune</i>	—	—	—	—	—	—	—	0
<i>hata nuni metene</i>	—	—	+	—	—	—	—	1
<i>hata nuni tamnone</i>	+	—	—	—	+	—	—	2
<i>hata msinae</i>	+	—	—	+	—	+	—	3
<i>hata nuni ueri</i>	—	—	+	—	—	—	—	1
<i>hata nuni sekane</i>	—	+	—	+	—	—	—	2
No. of landraces	3	5	2	4	2	1	1	18
Distance from Rohua (km)	0	0.5	1	2	3	18	10	

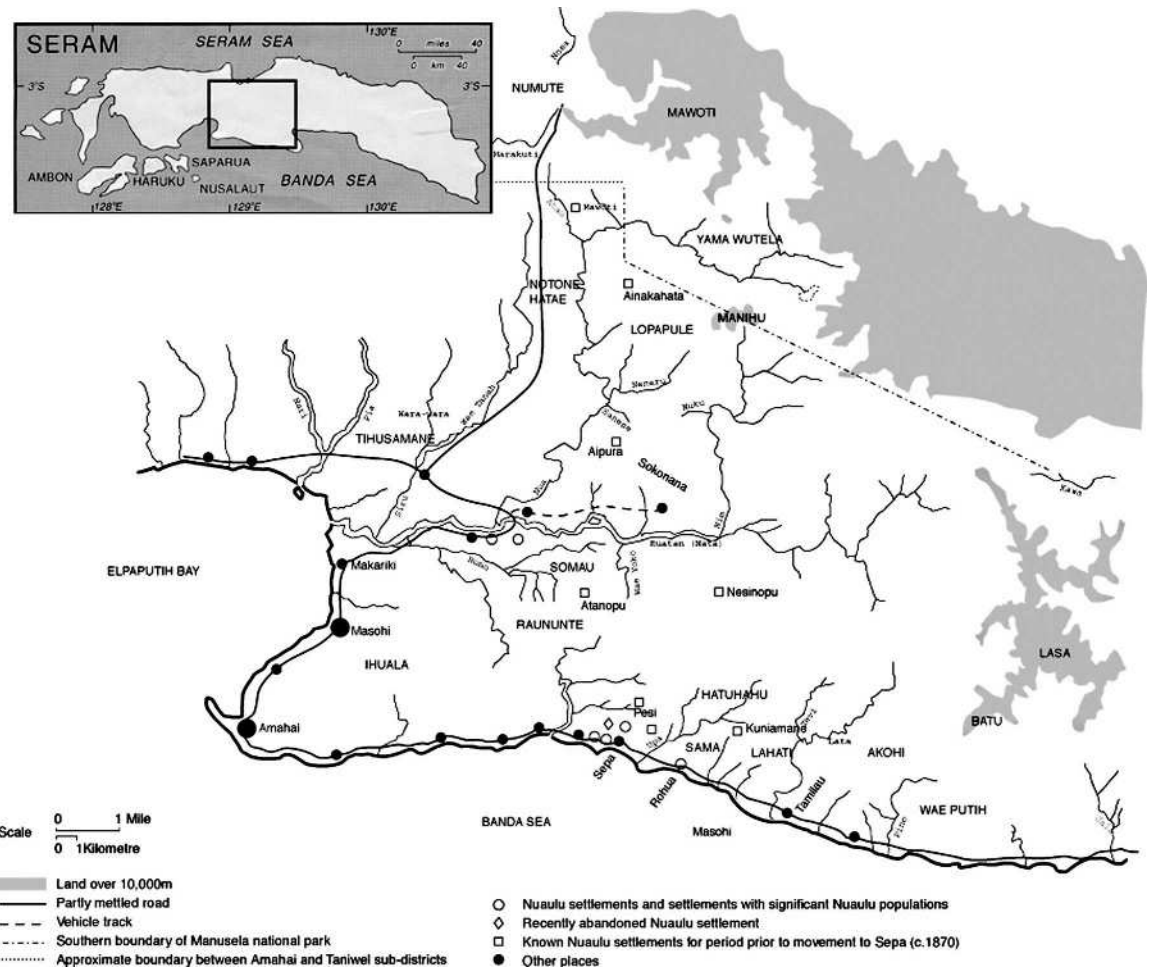


FIGURE 9.—Location of Nuaulu settlements and sago extraction sites in south Seram mentioned in text. Inset shows the map in relation to the island of Seram as a whole, including geographical coordinates.



near the village, for aesthetic reasons, to introduce culinary variety and in anticipation of potential management issues. In this—despite the assertion that there is little difference in starch and other key features between the landraces—Nuauulu are consistent with a more general model of diversity preference for other key starch crops. In more distant localities, fewer opportunities for redistribution are available. In these sites, although single landraces are free to spread vegetatively to produce mono-phenotypic areas with minimum human interference, an increased rate of sexual reproduction introduces a continuum of non-selected genetic diversity less easy to divide into specific folk types.

Contrary to what might be expected, *hata ai*, the non-spiny landrace, is not disproportionately represented in sites nearer the village, and in fact is better represented in one distant site, Somau. In Somau, an area where Nuauulu sago management, at least until the period of government resettlement policy in the eighties, was least intensive, spineless *hata ai* is cut of preference. The cutting of the palm encourages the natural growth and establishment of suckers since stands are always harvested so that a sizeable bole remains, from which sprouting can continue. Clumps more distant from a settlement are harvested less frequently, and are therefore in greater abundance, and with more opportunities to reproduce sexually. This tends to generate more unselected diversity. Clumps nearer a settlement tend to be fewer in number, most likely individual stands, where suckers are removed and planted elsewhere in cultivated areas. Such stands tend to be harvested before they have an opportunity to sexually reproduce. In such circumstances distinct landraces tend to be maintained. These management strategies, and the ecological dynamic which reinforces the patterning of diversity, are considered further below.

#### SUB-SPECIFIC GENETIC DIVERSITY AND CULTURAL RECOGNITION OF LOCAL CULTIVARS

The earliest mentions in the literature to sago palm diversity are found in the *Herbarium Amboinense* of Rumphius (1741:75; see also de Wit 1959), who reports four types of sago for Ambon that would now be placed in the species *Metroxylon sagu*. Of these, *tuni* (his *Sagus genuina*) is said to be most common, most tended and most planted, producing the best starch and best thatch. A second kind, *ihur*, (his *Sagus sylvestris*) is reported as being mainly found on Seram, and hardly at all on Ambon. He also reports *molat* (his *Sagus laevis*) and *Sagus longispina*. His *Sagus filaris* is now placed in the genus *Pigafetta*. Later writers (see Table 6; de Stuers 1846:374, Maier 1868:164) follow this basic pattern, though Maier adds two further types, *duri rotan*, evidently related to *Sagus longispina*, and *sagu batua*. Beccari (1918) presents an altogether more complex and geographically nuanced picture. For West Seram he reports the full range of Rumphian types, plus *duri rotan* and a new type, *putih* (*M. rumphii* var. *ceramense album*) for West Seram; but for Amahai he lists *molat*, *duri rottan* and four new types mostly closely linked to *ihur* and *tuni* under the specific name *rumphii*, divided into the varieties *ceramense rubrum*, *c. album*, *c. nigrum* and *platyphyllum*. Tichelman (1918–19:1069), writing specifically of Seram, lists the pre-Beccarian five types of sago, though *tuni* becomes *sagu merah*. Ruinen (1920: 504–505) also lists five types: the four

TABLE 6.—Comparison of types of *Metroxylon sagu* identified by different authors reporting from Seram and Ambon.

Rumphius Latin term	Rumphius folk term	de Steurs (1846)	Maier (1868)	Beccari (1918): Amahai	Beccari (1918): west Seram	Tichelman (1918–1919)	Ruinen (1920)	Deinum and Setijose (1932–1933)
<i>Sagus laevis</i>	<i>molat</i>	<i>molat</i>	<i>molat (sagus)</i>	<i>molat (sagus)</i>	<i>malat (sagus var. molat)</i>	<i>molat</i>	<i>laevis</i>	<i>molat (sagus)</i>
<i>Sagus sylvestris</i>	<i>ihur</i>	<i>ihur</i>	<i>ihur</i>		<i>ihur (rumphii var. sylvestre)</i>	<i>tuni merah</i>	<i>sylvestris ihur</i>	<i>(sylvestre)</i>
<i>Sagus genuina</i>	<i>tuni</i>	<i>tuni</i>	<i>tuni</i>		<i>tuni (rumphii var. micranthum)</i>	<i>tuni</i>	<i>genuina</i>	<i>tuni (rumphii)</i>
				<i>merah (rumphii var. ceramense rubrum)</i>				<i>micranthum</i>
				<i>putih (rumphii var. ceramense album)</i>	<i>putih (rumphii var. ceramense album)</i>			
				<i>hitam (rumphii var. ceramense nigrum)</i>				
				<i>ceram (rumphii var. platyphellum)</i>				
<i>Sagus longispinum</i>		<i>makanaru</i>	<i>makanaru</i>	<i>makanaru</i>	<i>makanaru longispinum (rumphii var. micranthum)</i>		<i>merah</i>	<i>(longispinum)</i>
			<i>sagu batua (Hoamoal and Buru)</i>					
		<i>rottan</i>	<i>duri rottang</i>	<i>duri rottan (micranthum)</i>	<i>rottan</i>	<i>(rumphii var. rotang, sub-var. makonaru)</i>		<i>duri rotan</i>

Rumphian types plus *Metroxylon micracanthum*, placed by Rumphius in his *Sagus genuina*. Deinum and Setijose (1932–3:106) resort to the four Rumphian types, though with *molat* as synonymous with *sagu perumpuan* (*Metroxylon sagus*) and the local term for *longispina* being listed as *merah*.

As noted, all types distinguished in Table 6 would now be subsumed within the single species, *Metroxylon sagu*. Most of the attempts to distinguish different types appear to follow a combination of the accepted Rumphian distinctions and observations based on local folk classifications. Beccari (1918:158–162), however, was unable to identify with certainty all varieties mentioned in the *Herbarium Amboinense*, and cautions that the local names used by Rumphius may vary from one place to another and between individuals. He does attempt to separate varieties and sub-varieties on the basis of fruit characters such as size and shape, though Rauwerdink (1986:179) has noted that such differences may occur within the inflorescence of a single palm. This suggests that much variation has more to do with age and location of the fruit in the inflorescence, rather than genetic differences between individual plants.

Various contemporary writers report four basic named cultivars for Ambon island. Writing of Poka, Sastrapradja and Mogeia (1977:113), list *sagu mulat* (spineless), *ihor* (high density of short spines), *sagu tuni* (spines of intermediate size) and *sagu makanaro* (long spines). Brouwer (1998:357) reports four cultivars for Hila: *molot*, *ihur*, *tuni*, and *makanalu*. Here *tuni* is regarded as ‘original, natural’, socially controlled, yielding the best quality of starch and good quality thatch, but is now virtually impossible to propagate, *ihur* is more easily planted and equals *tuni* in productivity, though its leaves are not so fine. Brouwer reports that *ihur* has only been known in Hila for two to three centuries, having been introduced from Seram via Iha, on Saparua. This observation is consistent with what Rumphius has to say. Elsewhere in Maluku, numbers of recognized landraces are reported by Schuiling et al. (1993:39, 46, 50) as follows: Toliwang Halmahera (4), Kao Halmahera (5), Ternate (4), Sorong (2), Salawati (10). Yoshida (1980) lists eight landraces for Galela on Halmahera. Schuiling (1995:49–59) lists 28 reports (of varying quality) giving names for sago landraces, both from the literature and from his own work. Names vary between two and 24, with a mean of 8.21. Suharno (1997:133–134) reports eight named landraces for the Alune of Lumoli, West Seram. Ehara et al. (2000) report four landraces for Limau and three for Kao in northern Halmahera, and similar numbers for various sites in Ternate, northern and southeast Sulawesi. However, in many studies, including that by Ehara, it is difficult to be confident that all local recognition of landraces has been reported. Where there are just two types these are almost always spiny and spineless.

For historical reasons, Ambonese names have become comparators in assessing *Metroxylon sagu* diversity, in Maluku at least, and since sago germplasm moves between different language areas there has to be some common means of identifying difference. Thus the terms *tuni*, *ihur*, *molat* and *makanalu* (or its cognates), and possibly *duri rotan*, have wide currency, and in many cases it is possible to equate them with local names for basically similar genetic material. Thus, Schuiling et al. are able to equate one of the Kao Halmahera names with (red) *molat (merah)* and another with (white) *molat putih*, and some Ambonese

*molat* has evidently been conveyed as far east as the Sepik in Papua New Guinea. The only landrace that can be unequivocally identified in this way is one that is spineless. As far as the Nuauulu landraces are concerned, *hata ai* certainly equates with *molat*, though the precise matching of the others is difficult. *Tuni* and *ihur* seem to be used for the small and fine spine landraces (*nuni mane*, *nuni uakane*, *umena*, *tamnone*, *napaune* and *nuni sekane*), though at what point one becomes the other is unclear. By contrast, *makanalu* and its cognates covers the long spine types *nuni nasinana* and *nuni weri*, including the red blotch form, *msinae*.

How these culturally recognized differences, and the varying degree and kind of lexical recognition, map on to any common genetic reality is still not properly understood. Rauwerdink (1986: 172–5) has revised the taxonomy of *Metroxylon sagu*, placing the various morphological types into four formae. He characterizes these as follows:

1. *sagu*: (largely the Rumphian *Sagus laevis*), with a leaf sheath, petiole and rachis smooth and devoid of spines, and with smooth inflorescence bracts. Pinnae are sometimes spinulous.
2. *tuberatum*: this forma is new to Rauwerdink, and groups palms where the leaf sheath is covered with irregular knob-like structures, and where the petiole, rachis and inflorescence bracts are smooth. Pinnae are sometimes spinulous.
3. *micracanthum* (the Rumphian *Sagus duri* rottang), with leaf sheath, petiole and rachis with spines up to 4 cm from an early age, and inflorescence bracts smooth and with scattered spinules.
4. *longispinum* (the Rumphian *Sagus longispina*), with leaf sheath, petiole and rachis with spines 4–20 cm, and inflorescence bracts with spinules, scattered as transverse series.

Rauwerdink (1986: 179) claims that for each part of the palm and for each developmental stage, spine characters are independent of age and are therefore, after all, diagnostically useful for taxonomy. The fact that a spiny palm may produce spineless seedlings, simply indicates that it is genetically heterozygous for this character. According to Rauwerdink (1986: 179–80), the forma *sagu*, *tuberatum* and *micracanthum*, have been long domesticated, almost always being cut before fruits even start to develop. In *longispinum*, fruits do frequently develop, but this taxon is much less cultivated. Recent work on pollen has proved insufficiently conclusive to be able to confirm that classification based on macro-morphology and micro-morphology is not in agreement, as some have suggested (Flach 1997: 19; Schuiling et al. 1993: 28).

Further genetic and anatomical work may yet reveal more consistent sub-specific regularities that find expression in individual landraces. However, for the present, the evidence suggests strongly that each region (perhaps to some extent reinforced through island separation) has its own landraces, probably sustained through vegetative reproduction (Flach 1997: 47), and that broad-based regional classifications are no doubt always going to be problematic in making sense of the local level (Dransfield 1999:7). Thus, given the variability of *Metroxylon sagu* we should be wary of trying to force Nuauulu landraces into the Ambonese classification, let alone anything wider. It may be more accurate to

view local landrace categories as a means of expressing a range of interlinked characters of morphology and practical use that in a particular area are sufficiently stable for recognizable differences to be widely shared and so represented in a population. In the next two sections I show how *M. sagu* diversity in the Nuauulu area of south Seram is related to a particular historical ecology, reinforced through patterns of management and tenure.

#### THE HISTORICAL ECOLOGY OF SAGO PALMS ON SERAM

The distribution of palms in anthropogenic rainforest biotopes is probably very different from what we would expect to find in undisturbed habitats. Especially in larger cleared areas, people can deliberately space and move palms, altering patterns that would otherwise arise through untampered suckering, fruiting and dispersal of seed. In Maluku, people can cultivate quite high densities of *Areca catechu* L., *Arenga pinnata* (Wurmb) Merr., *Cocos nucifera* L. and *Metroxylon sagu*; and elsewhere in Indonesia, of *Borassus flabellifer* L. and *Elaeis guineensis* Jacq. *M. sagu* is characteristically a palm of swampland that provides optimal conditions for its growth and reproduction. It also grows in alluvial and peaty soils where few other crops can be maintained without drainage (Ehara et al. 2000). Where it is found growing in dry land, the area is seasonal swamp, garden or plantation, usually offering good evidence for human transfer.

The readiness with which *M. sagu* reproduces vegetatively through suckers, its production of clumps and its mode of sexual reproduction that favours dispersal of seed around the parent plant suggests that under non-artificial conditions it inevitably forms large monospecific patches in swampy areas. Whether this mode of colonization provides a sufficient explanation for the large areas of sago-dominant swamp forest in New Guinea, Seram, Halmahera, Buru, Aru and elsewhere is doubtful. This scale of monospecificity would seem to require some form of human interference. Thus, the deliberate cutting of immature stands, and of mature stands which have not fruited or dispersed seed, appears to encourage sucker growth, as noted long ago by Forrest (1969 (1779):40). In the case of Seram, constant human interference through cutting and replanting suckers within the swamp forest areas has likely fostered the expansion of these areas and ensured their monospecificity. The overall appearance of this kind of sago landscape is, as Corner (1966:315) suggests, "fantastic and awesome", or as Malinowski (1922:378) reflects, "antedeluvian-looking"; though to characterize it as "Palaeozoic" is to misleadingly encourage the false assumption that such landscapes are other than largely human creations.

On Seram, we can distinguish six microenvironments in which *Metroxylon sagu* is found:

1. Inland sago swamp, usually at sea level along major rivers. In south Seram, within the Nuauulu extractive area, at Somau (Figure 9: also known as Tihun in the local vehicular language) there is very little vegetation apart from sago. There are some pandans that are used for firewood and construction purposes, and a few ferns and fungi, but little else. Movement by foot is difficult, though there is some seasonal variation in the depth of the water

and muddiness. Nuauulu use the expression, *soma tai ia* to describe areas that are as swampy as Somau. The Somau area, south of the Nua-Ruatan confluence, predominantly comprises *hata ai*, spineless sago (the *sagu* forma of Rauwerdink). Further west, towards the mouth of the Ruatan, near the settlement of Makariki, spiny landraces predominate. These areas indicate the extensiveness and antiquity of sago management (see also Tichelman 1918–1919:1019).

2. Smaller patches of, usually seasonal, sago swamp with high concentrations of sago, along smaller inland rivers. These are often near old village sites, such as at Mamokoni (formerly occupied by the clan Numanaita), inland from another hilltop site at Amatene
3. Small patches of sago in old village sites in non-swampy areas, often high up, for example at Amatene (near Sepa, in Figure 9). Where there is clear recent or historical evidence of type 2 and 3 patches being deliberately created and maintained they are sometimes described by Nuauulu as *nisi hatane*, “sago gardens” or, moreso in 1996 than 1970, *rusun hatane* (cognate with Ambonese Malay *dusun*, meaning “orchard”). Both terms echo the old Dutch description of these areas as “sagotuinen” (Fortgens 1909). Typically, such gardens are found in areas where the water table is high or the soil is moist, such as along stream banks.
4. Patches of sago at the mouths of smaller rivers, often in inter-tidal brackish water. Here pools of permanent brackish water accumulate behind a barrage of shingle thrown up by high monsoon tides on the edge of which saline-tolerant sago palms appear to flourish (Flach et al.1977:193; though see Rhoads 1982:20). Most of these river mouth groves belong, not to Nuauulu, but to the politically dominant settlement of Sepa.
5. Individual stands or clumps in garden land. Sago may be planted in old swiddens (*nisi monae*), one to three years after first clearing (*hata monae*), or in forest fallow (*ahue*), after three years since clearing (*hata ahue*).
6. Individual stands or clumps in village areas.

Rhoads (1982: 24) distinguishes three levels of sago management: repeated extraction as an unintended management technique enhancing sago palm vitality, horticulture involving deliberate planting of suckers, and palm cultivation, involving clearing rain forest canopy or creating artificial swamps (Flach and Schuiling 1989:259). The reproductive patterns, scope for germplasm exchange and subsistence potential are different for each of the microenvironments described above, suggesting that this threefold distinction might have to be somewhat modified.

In areas where human modification is intermittent and limited, such as in the extensive sago swamps along the Ruatan river (type 1 localities), many stands flower, fruit, produce viable seed and successfully reproduce sexually. This introduces diversity into the genetic stock, which is selectively fostered by Nuauulu, who deliberately transfer germplasm to localities nearer the village through transport of suckers or seedlings. Transfers do not appear to occur in the reverse direction. Leaves, petioles and woody leaf sheaths are less likely to be harvested in such areas due to their relative remoteness. Here also, felling

exposes young shoots to sunlight and spaces created for the purpose of processing sago allow palms to achieve advantages over other competitors.

Type 2 localities are generally entirely (and more recently) anthropogenic, their smaller size and greater accessibility restricting opportunities for cross-pollination (Flach and Schuiling 1989:261), and therefore hybridization and economic extraction. I counted 47 stands of all growth stages in a one hectare plot of this kind on the river Upa, of which only three stands were mature enough for cutting.

In areas nearer the village (locality types 3–6), where all palms are carefully tended, and rarely allowed to reach maturity, diversity is introduced by altering the ratios of existing phenotypes, introducing new germplasm from elsewhere and occasionally taking advantage of a somatic mutation. Clumps then spread depending on the fecundity of suckering. If one landrace sends out suckers at a greater rate or in greater quantity than another, it will tend to colonize a cultivated patch, unless steps are taken to remove the suckers. Nuauulu remove suckers from more remote sites to sites of types 3–6 either opportunistically, simply taking what is accessible to increase stock nearer the village, which given the greater diversity of more remote sites, tends to have the effect of anyway increasing diversity; or they may consciously take germplasm on the basis that it is from a landrace known to be not already represented at a particular near site, or more specifically on the basis of the suckers coming from individual palms which are known to have been more productive or of higher quality in the recent past.

Nuauulu clear away dead leaves from the trunk and take well-developed leaves for thatch. It is possible—as is the case with *sagu tuni* in Ambon (see above)—that particular landraces are preferred for thatch, in which case leaf quality may also be a factor influencing selection. However, I have no data on this subject. Certainly, encroaching undergrowth may be cut back, young clumps thinned and excess suckers pruned out, which increases leaf formation (Flach 1977:163) and most likely starch accumulation as well. Some suckers are carefully removed for transplanting elsewhere, so as not to damage the parent stand and ensure survival. These are usually those that are well-developed but not more than a year old, generally from an already mature palm. Before planting out, or while in transit, suckers are sometimes nursed for a short while at the end of bamboo water conduits serving garden huts or villages. They are subsequently planted in a small hole and well-watered. Nuauulu use a wooden dibble, as they believe that this will encourage pith of a desirable quality, whereas a metal dibble leaves the pith tough (Bolton n.d.). Although Nuauulu know of and understand sexual reproduction in sago and take advantage of it as a source of new diversity, there is no attempt to deliberately plant from seed. Surprisingly, there is high intra-landrace phenotypic variability despite clonal propagation.

Given the situation described, the distinction between cultivated and non-cultivated becomes a difficult one to make. Certainly, more remote stands are less likely to be tended, and stands in the village tended more than others, but between these extremes there is a continuum. It is understandable, therefore, that *Metroxylon sago* growing in extensive patches on larger islands has in the past been reported as being “wild” or “semi-wild” (Davis 1988), while in accessible

patches on small islands, such as Ambon, it is described as "cultivated." The distinction between domesticated and non-domesticated varieties is equally problematic, as is an older view, sometimes still heard, that non-spiny types are more likely to be semi-domesticated than spiny types. Thus, when government and other reports distinguish, as for Salawati, between nine "planted" varieties and one "wild" variety we have reason to be suspicious. Often when official reports distinguish between wild and planted, locals do not agree (Schuiling et al. 1993:50). In the difficulty of distinguishing stock modified by human interaction from that not so modified, the situation is in some respects similar to that described by Shigeta (1996) for *Ensete ventricosum* (Welwitsch) Cheesman, and Elias, Rival and McKey (2000) for *Manihot esculenta* L.

Having stressed the difficulty of distinguishing between cultivated and non-cultivated, wild and domesticated (which the Nuauulu themselves do not do), it is clear that most sago consumed by the Nuauulu is derived from clumps in zones 2 to 5, which rarely flower and which regenerate by means of suckers. In other words, the stands are from areas where management is most active. The same phenotypes appear in both cultivated areas and in distant unmanaged swamp forest; they are generally indistinguishable and interchangeable, suckers from the latter often being collected for planting in areas nearer the village. There is no evidence that smooth landraces are more frequently transplanted in this way. This is despite the fact that the people were perfectly aware of the fact that spineless varieties can give rise through sexual reproduction to spiny ones and *vice versa*.

During the period April-August 1970 I calculated that almost 54 percent of all sago consumed in the village of Rohua was from type 1 and 2 locations, which I then described as "non-domesticated sources." This amounted to about 1,056 kilocalories per head per day (300 grams mean weight of moist flour), representing 76 percent of the total weight of non-domesticated plant resources converted into available food energy. Since these data were obtained largely during the wet season, when conditions are least favorable to the collection of sago from these more distant swampy areas, the real figures are quite probably higher. The greatest proportion of locality 1 and 2 sago comes from the rich, high-density, sago palm forest (for much of the year swamp forest) areas towards the confluence of the Nua and Ruatan rivers (Somau), an area of some 48 square kilometers, approximately 16 orthographic kilometers from the Nuauulu village of Rohua over hilly and riverine afforested country. Under normal circumstances this is a six-hour journey. In addition, palms are also cut at suitable localities, usually where the land is permanently damp or swampy, on other rivers flowing southwards into the Banda Sea as far eastward as the mouth of the Jala.

The total energy derived by the Nuauulu from cultivated resources (gardens and groves) amounts to something in the region of 1,813 kilocalories per head per day, of which some 902 kilocalories come from sago. During a test period, 154 man-days were devoted to the extraction of flour from cultivated palms, some 37 percent of the total time spent on activities involving the extraction of domesticated resources. But it is the very ease of accessibility, coupled with the relative scarcity of cultivated stands, that almost inevitably leads to their being cut prior to flowering, when the yield and quality of starch have not yet



reached their possible maxima. In short, yields from different localities show a general tendency to increase the greater the distance from the village.

The importance of *Metroxylon sagu* as a long-term resource is, therefore, inextricably linked to an ecology of human modification. Once a palm is planted it will continue to grow on a site for generations. By preventing stands from flowering and allowing a few suckers to develop, clumps may be extracted from for centuries. Sago never exhausts the soil, following the principle of the greater proportion of a plant above the ground the less reliance on the soil for nutrients, and perhaps also because the stump and most matter other than the processed starch is left to disintegrate in situ after harvest. Unlike areas devoted to the cultivation of coconut and clove, which are largely a recent response to a cash economy and coastal conditions, sago groves appear to have been created and maintained by the Nuauulu as a part of their traditional assemblage of subsistence activities over some hundreds of years. The evidence for this lies partly in the physical examination of the composition of old settlement areas (Figure 9), partly in Nuauulu assurances that some of the inland sago areas were originally planted by their mountain ancestors (who can be identified with some certainty using triangulated genealogical data), and partly in the current practice of highlanders in the interior of west Seram, where coconut and clove cash cropping has yet to establish itself as a viable source of income. The presence of sago in the same locations over long periods of time has important implications for property relations, palm management and for the redistribution of the harvested product.

### SOCIAL CONTROL OF SAGO RESOURCES

Patterns of ownership influence sago palm management and extraction, and have an impact on the distinctiveness, distribution and ecology of the cultivars. All sago palms on Seram are owned, in so far as they are to be found in the territory of one clan or another, but some are remote and never managed, and it is only through the cultural vocabulary of "ownership" that the wild-cultivated distinction is perpetuated.

If social accessibility is phrased in terms of rights of access, three different categories of ownership may be recognized: village rights, clan rights and individual/household rights:

1. *Hata niane* are areas of mostly naturally-propagated palms in various localities to which all Nuauulu have equal rights of access. Such rights usually apply to type 1 localities such as Somau. In the case of Somau, access is shared with other local non-Nuauulu peoples, such as those from Nuelitetu and Sepa, each group having its own traditional spatial foci of extraction. Thus, the Nuauulu village of Rohua extracts from the areas known as Kamnanai Ukune (betel pepper tree) and Nusi Ukune (lemon tree), signaling trees once planted in these areas by those who now extract from them. Continuous extraction from particular localities has led to the construction of temporary and semi-permanent shelters, and although it is generally agreed that in these areas no one individual or patrilineal clan has rights over either land or sago, customary usage and convenience have led to the association of particular localities with particular groups. It is important to note that while

management is minimal, access is common rather than open (McCay and Acheson 1987:7). These resources have, with the arrival of new transmigrants in recent years, been subject to dispute, as outsiders have interpreted them as open-access resources. This has led to conflict (Ellen 1999, Ellen 2004b).

2. *Hata ipan* (or *ipane hatana*, where final *lal* indicates the plural form) are individual stands, clumps or areas in which rights of access are vested in a clan (*ipan*, *ipane*) corporately, and which are usually described with reference to the specific clans to which they belong: thus *Soumori hatana*, *Neipane hatana*, and so on. These areas are mainly type 2 and 3 localities, and may include *sin wesie*, areas of protected forest, guarded by a single clan for ritual purposes, say house building or ceremonial occasions (Ellen 1998b). *Sin hatane*, therefore, are a type of *sin wesie*, special sago reserves maintained to ensure a supply of sago for clan feasts and exchanges. The first time sago is taken from one of these reserves it can only be used for making hard biscuits (*sikenae*), which are treated by Nuaulu as ritual food in contrast to mundane sago porridge (*sona*). Even sago growing in such areas that has reached fruition must be allowed to rot, unless the prohibition on extraction has been lifted by a clan head.
3. *Ruaka hatana* are individual rights of access to sago palms. Such rights, usually found in type 4, 5 and 6 localities, are established by the individual who first planted the palm by transplanting a young sucker or seedling, and may be transmitted to their offspring through the male line. Given its mode of vegetative reproduction, clumps of sago palm (*mata hatane* or *hata matae*) may be owned in the same way. If such clumps are planted in patches or on clearly demarcated owned land, and suckers spread into land owned by another person or group then that person or group has a right to remove suckers, otherwise they will be deemed to belong to the owner of the parent clump (c.f. Brouwer 1998). Although *ruaka hatana* is regarded as a perfectly legitimate and separate form of ownership, the passage of time tends to transform individual rights into undifferentiated clan rights; *ruaka hatana* becoming *ipane hatana*. This social transformation is encouraged by the length of time taken for an individual palm to mature, and by the process of suckering and clumping. In any event, kin and affines have the same rights of access to palms for which individual ownership is acknowledged, as they are regarded as having with respect to undifferentiated clan rights in palms. Although sago palms in this ownership category are never subject to *sin hatana*, they can theoretically (but in practice rarely) be subject to a *sasi* (*hatane*), a prohibition on extraction for a limited time period (see e.g., Zerner 1994). They are, however, often protected by an *akatanai*, a type of scare charm (*wate*) used to guard against theft of sago when it is being worked. This consists of the 'heart' of the sago (the stem apex) or inflorescence, hung from a bamboo frame by rattan (Figure 7e).

Given the character of tenure, the growth and reproductive habits of *Metroxylon sagu*, and for other practical reasons, it is difficult to calculate the number of palms per individual or household. Questions about ownership of sago palms in general tend to elicit estimates of numbers of stands/clumps in the

*hata ipane* and *ruaka hatane* categories. In 1970–1971 I conducted a census of tree ownership in Rohua, aware that the distinction between individually-owned and collectively-owned trees was fuzzy. When asked leading questions about tree ownership, Nuaulu informants were most likely to report as *ruaka* ownership of commercially valuable trees, such as clove, nutmeg, coconut and coffee, rather than sago. Such trees can be converted into natural product commodities (Ind. “hasil”). Although there is some trade in sago, sago palms in 1971 were still seen as subsistence resources identified with groups rather than individuals, and therefore tended to be under-reported in the survey. Even so, few sago palms would fall in the *ruaka* category, and then only those in gardens, in the village area or in groves near the village (Mon, Lata, Rohua, Awao, Upa, Lihuru, Monone, Joko, Sunukune, Kau, Turiaro).

An additional practical problem in conducting any census of sago palms is knowing whether to count clumps or stands, and stands of what height or degree of maturity. In the survey stands of extractable size were counted. Of 26 male household heads surveyed, four reported owning no *ruaka* sago, 11 reported between one and 10 stands, four between 11 and 20 stands, and six 21 stands or more (including some with up to 30 stands at different stages of development). The mean for extractable stands was 17.2. At the higher end I suspect a merging with *hata ipane*. So, at best the number of *ruaka* palms per household can be said to be highly variable. Approximately 9.5 ha of a total of 102 ha under cultivation can be described as sago grove land, or about nine percent. This, of course, does not take account of individual palms in mixed gardens.

The ownership and management of sago palms is additionally influenced by overall patterns of land tenure, which in the coastal areas of south Seram are complex. This in part reflects the historical pattern of movement of different indigenous Seramese clans and villages. It is also affected by patterns of land transfer (including sale), land rental and other forms of short-term occupancy, including buying of a harvest (whereby a person may buy the harvest of a particular palm while the rest of the clump and land reverts to the original owner), and increasingly since the 1980s, by immigration from outside Seram.

## DISCUSSION

In this article I have shown how the traditional management of *Metroxylon sagu* is often more intense than many previous reports suggest. At the same time, the palm is probably not as fully domesticated as, say, date (*Phoenix dactylifera* L.) or pejobaye peach (*Bactris gasipaes* Kunth) palms, which do not exist undomesticated anywhere in their distribution. But although an important food source, sago palms do not receive the same level of attention (especially across a large span of time and geography) as many other crops, both palms and non-palms. Cultigens such rice, maize, potatoes and dates have, additionally, been selected (intentionally or unintentionally) for a variety of microclimates, whereas sago is restricted to a more narrow range of habitats. Nevertheless, the time and effort spent by Nuaulu on sago extraction and intentional vegetative reproduction undeniably constitutes a selective pressure generating distinguishable morphotypes, especially as it is now recognized that even low-level

TABLE 7.—Numbers of lexically recognized landraces for selected Nuauulu cultivated plants.

Palms		Non-palms	
Species	No.	Species	No.
<i>Areca catechu</i> L.	5	<i>Capsicum annuum</i> L.	9
<i>Arenga pinnata</i> (Wurmb) Merr.	1–2	<i>Colocasia esculenta</i> (L.) Schott	9
<i>Cocos nucifera</i> L.	10	<i>Dioscorea alata</i> L.	11
<i>Metroxylon sagu</i> Rottb.	11	<i>Dioscorea esculenta</i> (Lour.) Burkill	8
<i>Salacca zalacca</i> (Gaertner) Voss	1	<i>Manihot esculenta</i> Crantz	11
		<i>Musa x paradisiaca</i> L.	37

tolerance and protection of semi-domesticates may be sufficient for this purpose (e.g., Casas et al. 1996).

Most palm species, suggests Dransfield (1999:11), display wide variability in morphological characteristics, “within individuals..., between young and mature forms..., and within populations of mature plants.” The botanical and ethnobotanical evidence provided here for *Metroxylon sagu* sub-specific diversity supports this assertion, and suggests that in this species at least variability does not easily translate into clear and consistently separate cultivars. In the Nuauulu case, the cultural expression of this diversity in terms of distinctly recognized landraces is influenced by the difficulty with which stable cultivars can be established, despite intrinsic genetic variation. Indeed, it might be technically more accurate to describe what Nuauulu recognize for *M. sagu* as clonal variation rather than landraces in the usual sense. This reflects an interaction between the reproductive biology of the species and forms of management that favor vegetative over sexual reproduction, through the harvesting of immature stands. These practices are reinforced through particular anthropogenic ecologies and forms of social ownership. Despite this, Nuauulu recognition of distinct local sago landraces has been shown to be more extensive than demonstrated in any previous comparable case study conducted in the Moluccas, or anywhere west of New Guinea (Schuiling 1995: 49–59).

Some Nuauulu non-palm cultigens readily hybridize, and much of the diversity found, including that which is lexically encoded, can readily be explained in this way (e.g., *Musa*, *Curcubita*, *Capsicum*). By contrast, Nuauulu palm cultigens and semi-cultigens show far fewer labeled landraces (Table 7). This pattern is reflected in lexical data from other studies (Table 8). In botanical terms, a comparison of *Metroxylon sagu* (a slow-growing perennial), or indeed any other palm, with say rice (an annual) may seem quite invalid without a discussion of such matters as generation length and breeding systems. However, my starting point has been ethnobotanical: people’s recognition and codification of diversity, and what they make of it, and what we might learn from it. Therefore, despite evident genetic variability within the species, it is possible that palms managed for their starch diversify and form stable cultivars somewhat less than other cultigens, perhaps reflecting the fact that palms take longer to reproduce sexually than grain and tuber crop annuals. It might also be related to the relative importance of vegetative as opposed to sexual reproduction, though this is certainly not a limiting factor in the case of, for example, manioc in lowland

TABLE 8.—Numbers of (lexically-recognized) landraces for selected domesticates in other studies.

Species	Number of landraces	Location	Sources
<b>Palms</b>			
<i>Areca catechu</i> L.	3	Bunaq, Timor	Friedberg 1990:214
<i>Cocos nucifera</i> L.	9–13	Solomons	Eyzaguirre and Batugal 1999
<i>Cocos nucifera</i> L.	14–17	Kerala, India	Thampan 2000
<b>Non-palms</b>			
<i>Colocasia esculenta</i> (L.) Schott	43	Wola, New Guinea	Sillitoe 1983:37
<i>Ensete ventricosum</i> (Welwitsch) Cheesman	71	Ari, Ethiopia	Shigeta 1996:236–239
<i>Ipomoea batatas</i> (L.) Lmk	63	Wola, New Guinea	Sillitoe 1983:29
<i>Manihot esculenta</i> (Crantz)	50	Aguaruna, Peru	Boster 1984:38–39
<i>Oryza sativa</i> L. <i>Pandanus brosim</i> Merr. & Perry	89	Baduy, West Java	Iskandar and Ellen 1999
<i>Pandanus julianetti</i> Martelli	45	Wola, New Guinea	Sillitoe 1983:45
<i>Saccharum officinarum</i> L.	12	Wola, New Guinea	Sillitoe 1983:84
<i>Solanum tuberosum</i> L.	30–40	Quechua, Peru	Brush 1991:156
<i>Zea mays</i> L.	12–17	Tzetzal, Mexico	Brush 1991:158

South America, or the traditional starch crops of Polynesia, such as taro. In this latter case selection is for the most part of somatic mutations through continuous vegetative propagation, and with very high numbers of local named clonal cultivars. On the other hand, within the Arecaceae, date, peach palm and possibly salak (*Salacca zalacca* or *edulis*), which reproduce asexually and sexually and are harvested for their fruits, have many cultivars, and are generally more typical of other morphologically differentiated food sources. By contrast, the sago palm, which in anthropogenic contexts reproduces mainly by vegetative means, disproportionately sustained as a reproductive strategy by human harvesting before fruiting and the deliberate transplanting of suckers, has relatively fewer distinct cultivars. Given that most sago propagation is vegetative and sexual reproduction is through obligatory cross-pollination, it is to a large extent the clonal variation in sago that is reflected in local names. This is now threatened by destruction of sago lands through resettlement, swamp drainage, movement to other crops and, in some places (such as Malaysia), the introduction of high-yielding plantation varieties.

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#### NOTE

<sup>1</sup> The term *keystone species* derives from an architectural metaphor (Paine 1969) introduced into the literature on conservation and ecology to indicate species whose trophic and other characteristics enhance biodiversity and which are crucial to the survival of particular ecosystems (de Maynadier and Hunter 1994). Its meaning has been extended recently in ways that have led some to question the clarity of the concept. For de Maynadier and Hunter (1997:69), the current consensus ‘identifies keystone species as those that have a greater role in maintaining ecosystem structure or function than one would predict based on abundance or biomass’, though some still use it to describe species which occupy a critical role regardless of abundance. In an ethnobotanical context, Meilleur (1994:269) has suggested *keystone societies*, referring to human populations which are essential to the maintenance of particular ecosystems and which enhance biodiversity through their subsistence practices, thinking for example of aboriginal Australians. More recently there has been a lively if inconclusive debate on the value of the concept, orchestrated by Cristancho and Vining (2004), Davic (2004) and Garibaldi and Turner (2004a, 2004b).

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