Distribution and variation in sago extraction equipment: convergent and secondary technologies in island southeast Asia

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Abstract

It is argued, following François Sigaut, that the way elements of technology are invented, borrowed and re-combined challenges the notion of 'technical lineage', with its implication of 'successive orderly accretions'. The contention is examined in relation to pith removal equipment used in palm starch extraction in island southeast Asia and Melanesia, which is considered additionally instructive because it yields some potential archaeological traces. The key archaeotypes – pounding and rasping tools – reflect convergent and secondary technologies that most likely were adapted to sago processing from other cultural domains. Pounders are found mainly in the eastern part of the geographic range, and rasps in the west. There is much variability in the distribution of types, even within a small area. Inferences are drawn relating to recent changes (for example, from stone to metal working edges, and from pounders to rasps), and concerning what we can learn from the distribution of different kinds of tool, including the likelihood of versions of the same tool co-existing in the same place, or being independently invented at opposite ends of the archipelago.

As Francois Sigaut (1994: 435) has warned, we need to be sceptical when it comes to the notion of 'technical lineage' in studies of the history, prehistory and archaeology of food procurement strategies. Aware that such an approach is often accompanied by a misleading implication of 'successive orderly accretions' of stylistic and functional elements, this article will attempt to demonstrate the point in relation to an aspect of palm starch processing. The distribution of this technology in southeast Asia displays a concurrent diversity of techniques in particular locations, the simultaneous development of similar technologies in widely separated places, and the interchange and hybridization of knowledge practices developed in relation to different genera of starch palms, all of which resonates with Sigaut's critique. I shall argue that the data suggest a need for a much more dynamic and nuanced view of the evolution of palm starch processing technology. Although some attention has been paid to the distribution of sago processing equipment in relation to issues in the archaeology and prehistory of Melanesia, the present article is original in its attempt to look at parallels and variations in an area delineated by the occurrence of sago-producing palms in island southeast Asia more generally. Within this general context it focuses more on the Moluccas, the material culture of which is less studied, but which in terms of the history and distribution of sago extraction and its technology is arguably transitional.

The extraction of palm starch for food is an ancient and widespread subsistence technique in large parts of southeast Asia and the western Pacific (Ruddle *et al*. 1978). In terms of the history of technology, it presents a paradoxical picture because while the methods are perceived as complex and its archaeology poorly understood, it is often hypothesized as a likely resource base for a pre-agricultural (certainly pre-cereal) phase of southeast Asian prehistory. In another paper (Ellen 2004a) I have examined this paradox in relation to that part of the technical process which involves converting stipe (stem or trunk) pith into raw flour. I show how the equipment employed displays a distribution which suggests that hand pressing technology is associated with *Metroxylon sagu* and foot pressing with other starch palms that are largely of importance west of Wallacea. As *Metroxylon sagu* spread westwards, so pre-existing local technologies were adapted to effect its processing. Unfortunately, this is an argument that is unlikely to be ever supported by extensive archaeological evidence, given the susceptibility of the equipment to rapid dispersal and decomposition, though there is some emerging evidence from Niah Cave in Sarawak for the presence of *Caryota mitis* and *Eugeissona utilis* starch, but not *Metroxylon*, in contexts suggesting its human use (Barton 2005). It is, therefore, an argument rooted for the most part in comparative palaeobotany, biogeography, ethnobotany and technology studies.

In parallel, this paper addresses the problem of 'technical lineage' identified by Sigaut, by examining an aspect of starch extraction technology (pith removal) that is significant because, of the various stages in the processing, it is one of only two stages (the second being cooking) that might eventually provide reliable archaeological traces. The key *archaeotypes* involved – a term I define below – are pounding and rasping tools. The technologies that rely upon these different tools are secondary in the sense that they are most plausibly adaptations to sago-processing from functions performed in other cultural domains. We can reasonably claim this to be so because in cognitive terms the

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extraction and processing of sago pith as food from inside a hard protective covering of spines is not immediately intuitive, involving complex problem-solving skills (Ellen 2004a: 89-91); and because pounding (or adzing) and rasping sago appear to be more specialized transformations of other more basic technical skills: on the one hand, hammering and cutting with respect to more tractable and obviously useful materials than sago pith; and on the other, rubbing abrasive objects on to less hard ones in order to reduce them to smaller pieces. The evolution of these processes is *convergent* in the sense of evolutionary biology: having evolved in separate contexts (such as working wood or stone) and involving different kinds of physical action they now produce the same basic end result, namely shredded pith.

The distribution and spread of palm starch extraction in the Indo-Pacific region

Following Dransfield (1981), we may distinguish five palm genera that have been part of the flora of adjacent parts of Sunda and Sahul since the Cretaceous, and that yield pith (or sago) which has been historically harvested by human populations: *Metroxylon*, *Arenga*, *Corypha*, *Caryota* and *Eugeissona*. These genera appear to have originated in the swamps and waterways on either side of the Banda Sea, subsequently extending their range through adaptation to marginal environments, colonizing habitats on new land forms. The most important of these genera in terms of human subsistence, *Metroxylon*, displays evidence of having an 'Austral' or Gondwanic origin. *Metroxylon sagu*, in particular, was probably domesticated quite early in New Guinea, and phytogeographical data suggest its much more recent westward diffusion, across Wallacea, from a likely centre of dispersal in New Guinea and the Moluccas, almost certainly assisted by human agents (Dransfield 1981, Rhoads 1982, Yen 1995). Data on the local genetic diversity of *M. sagu* provides further evidence for the hypothesis of westward human-assisted dispersal (Ellen 2004a, 2006). Indeed, for some thousands of years starch-yielding palms in the humid tropics have co-evolved with Post-Pleistocene human populations. The direct archaeobotanical evidence for this is limited, though we have palynology for *Borassus* and *Arenga* in contexts suggesting human management from 2500 BP, and possibly also for *Nypa* (Maloney 1994:147–9), and starch traces for *Caryota* or *Eugeissona* (Barton 2005). But this kind of evidence sheds little light on how the palms were being used.

Of the nine genera of starch-producing palms known to be utilized for food in island southeast Asia (Johnson 1977), only *Metroxylon*, *Arenga*, *Borassus*, *Eugeissona*, *Caryota*, and possibly *Corypha*, provide starch on a significant scale. Of these the most productive species is *Metroxylon sagu* (Watt 1908, Puri 1997, Johnson 1977). I follow convention by describing the processed starch of all these palms as 'sago', even though in the strict sense it should be reserved for *Metroxylon*. At the present time *Metroxylon sagu* ranges at its most easterly from Santa Cruz in the Solomon islands to southern Thailand and Burma in the west, via the island of New Guinea, the wetter parts of the Indonesian archipelago, the southern Philippines, and through the Malay peninsula. In Papua New Guinea, *M. sagu* is most concentrated along the great lowland rivers, especially in Sepik and Gulf provinces, though it is also important elsewhere; and in Indonesian Papua in the administrative districts of Jayapura, Merauke and Manokwari (Flach 1997:21). *M. sagu* is found and used all over the north and central Moluccas (especially on Halmahera, Buru, Seram and Ambon-Lease, Bacan, Sula and Obi), and in Aru. It is less important in Kei and Tanimbar, and almost entirely absent in the southwestern islands. Especially on large islands, it occurs mainly, though not entirely, in lowland swamp forest, where it is also at its densest. Apart from the Moluccas and lowland New Guinea, it remains an important source of food in central and southeast Sulawesi, in the Banggai archipelago east of Sulawesi, in the Mentawai islands west of Sumatra, amongst the Melanau and Kedayan in Sarawak (East Malaysia), and in parts of Brunei and Sabah (East Malaysia). It is cultivated commercially in the Indonesian province of Riau on the east coast of Sumatra (Bengkalis, Karimun, Lingga and as far north east as the isolated Natuna Island), and in some coastal regions of west Kalimantan around Pontianak, and along the Kapuas. The most important areas of modern commercial production are in Sarawak and Johore (Ruinen 1920:503–4, Flach 1997).

The literature on southeast Asian prehistory reveals a shift from an earlier *cultural ecology* model (Avé 1977), in which people adapt to swamp land and other restricting environments by extracting sago, to (more recently) a dynamic *historical ecology* model, in which people actively manipulate *Metroxylon* in various ways, creating specialized biotopes and anthropic landscapes, in order to meet specific food procurement and trade objectives. The extent to which human populations have actually managed sago has in the past been much misunderstood (e.g. Forrest 1969 (1779):42). However, recent ethnographic work has demonstrated that while sago extraction is certainly cost-effective, and nutritionally satisfactory as part of a broad spectrum food procurement strategy, at the same time ecologies that supply these advantages are themselves often the outcome of long-term environmental management practices. Rhoads (1982) distinguishes three levels of management: *repeated extraction* as an unintended management technique, *horticulture* involving deliberate planting of suckers, and *palm cultivation*, which involves clearing rain forest canopy or creating artificial swamps. However, the distinction between cultivated and non-cultivated, domesticated and non-domesticated, is sometimes difficult to sustain (Ellen 2006). Certainly, more remote palms are less likely to be tended, and palms in a village tended more than others, but between these extremes there is a continuum: hence the often reported description of sago palms as 'semi-wild'. The importance of *M. sagu* as a long term resource is, therefore, inextricably linked to a history of human interference. Once a palm is planted it will continue to grow on a site for generations. By preventing stems from flowering and allowing a few suckers to develop, clumps may be harvested for centuries. This has important implications for property relations, palm management and the distribution of extracted sago. In fact, the difference between cultivation, incipient arboriculture (proto-cultivation) and non-cultivation is often quite indistinct. While not all *Metroxylon sagu* areas can be said to be anthropic it is likely that humans have had a significant impact on its spread (Rhoads 1982:23-4, Ellen 2006), and that some so-called 'wild' palms may even be feral clumps of more ancient horticultures, such as in the Gidra, Gadio Enga and Waf areas of Papua New Guinea (e.g. Dornstreich 1977, Ohtsuka 1977, Oosterwal 1961).

Distribution and variation in pith removal technology

My specific concern here is with the origins, elaboration and spread of a subsistence technology. An adequate description of the technical sequences involved must distinguish the following prototypical technical actions: *cutting*, *splitting*, *chopping*, *pounding*, *creating a suspension*, *pressing*, *filtering*, *sedimentation*, *draining* and *heating* (Ellen 2004b). Each of these elements can be hypothesized as a cognitive archaeotype. *Archaeotype* is a term used in Ellen 2004a to refer to a discrete technical element, process or item of equipment, that is easily identifiable, shows evidence of antiquity and continuity of usage, and by virtue of which plausibly underpins a series of historically or conceptually related technologies. Each archaeotype will have been discovered many times by humans, and for this reason is presumably drawing on an evolutionary predisposition to identify and solve problems in particular ways. What is more difficult to explain are local combinations of these archaeotypes, that is how people learn to link them together in a process of qualitative innovation (Barnett 1953:7). In starch processing, the most complex operation is that which links separation of starch granules through pounding, the addition of water to create a suspension, the combination of pressing of wet pulp and filtering, and the retrieving of flour following sedimentation. There is much to be said for seeing the entire process, from cutting to heating, as a single integrated body of knowledge and material actions, but since starch separation (Ellen 2004a) has left no discernible direct archaeological trace, I focus here on the operation of pith removal through mainly *chopping* or *pounding*, and to a lesser extent by *grating*. These processes are associated with a characteristic equipment, parts of which can be potentially identified archaeologically. The artifacts examined here are those observed and collected by myself in the field, reported in the published literature, and located in the collections of the Rijksmuseum voor Volkenkunde in Leiden. These latter collections are methodologically significant because they are strong for both New Guinea and eastern Indonesia. Individual specimens in the Leiden collections are referred to here using the code RMV.

Specialized tools for extracting palm pith are known ethnographically and historically for the Indonesian archipelago and for (mainly the western part of) the island of New Guinea (Figure 1), the easternmost limit on the mainland likely being the Sepik basin (e.g. RMV 5526-366, RMV 1863-163). For the eastern part of New Guinea, Swadling (1996: figure 32) reports that the same tools used for wood-working are used for sago pith extraction. On the whole, throughout the range, general-purpose axes and bush knives, either metal or stone, are used for felling the palm, though in parts of New Guinea (for example in the Sepik) there are specialized palm felling tools (Figure 19). Tools for actually extracting the pith can be divided into two types: varieties of chopping or pounding tool, and rasps or graters. Descriptions of the first kind of tool vary, as do the technical actions attributed to it. The implement is variously described as a hammer, mallet, pith chopper, pounder, hoe, pick or adze, and the action as scraping, pounding, cutting and gouging. The confusion is understandable given that the same tool is used for various technical actions: to cut the pith away from the inside of the trunk, to pound the loose pith in the trunk, to loosen the starch granules and to scrape away pith adhering to the inside edge of the trunk. The action required to extract the pith using the second kind of tool can be described as *grating* or *rasping*. There are some reports of scraping tools which do not fit either of these categories, such as the hand-held unshafted coconut shell scrapers and serrated iron hoops found in Tikopia (Firth 1950:133–4). There are also museum specimens of single pieces of hard wood described as sago pounders, 'stampers' or 'sticks' for Buru in the Moluccas (RMV 1971–207) and for the Asmat area (RMV 1971–789, RMV 1889–309) on the 'Casuarina Coast' of southwestern New Guinea (Indonesian Papua, Kabupaten Merauke), which perhaps function(ed) after the fashion of rice pounders.

What I shall here call for convenience a *sago pounder* most closely resembles physically the tools whose names are also used to describe it, such as 'hoe', 'chopper' and 'adze'. It consists of a head with a working edge at one end, usually attached at an angle of 90 degrees to a handle. I here distinguish six basic types:

1. In its simplest form the pounder is composed of a single flexed piece of bamboo or a single piece of wood (Figure 2). In Piliana (central Seram) in 1975, I observed and measured a pounder made entirely of a single piece of *Pterocarpus indicus* wood (45.5cm shaft, 23cm blade) which had a metal ferrule combined with a stone flake cutting edge. Wooden pounders of a similar design are known for Halmahera (RMV 5382–12), for the Abelam of the Sepik valley (RMV 5526–366) and for the Asmat on the southwest coast of New Guinea. The Asmat examples (e.g. RMV 1698–65, RMV 3070–297) often have a replaceable bamboo sleeve on the working head to provide a more appropriate cutting edge.
2. More common is a tool with a head hafted through a hole in the handle. The head and handle can be of wood (Figure 3), or the head of wood and the handle of bamboo (Figures 4 and 5). The Nuaulu all-wood pounders of this

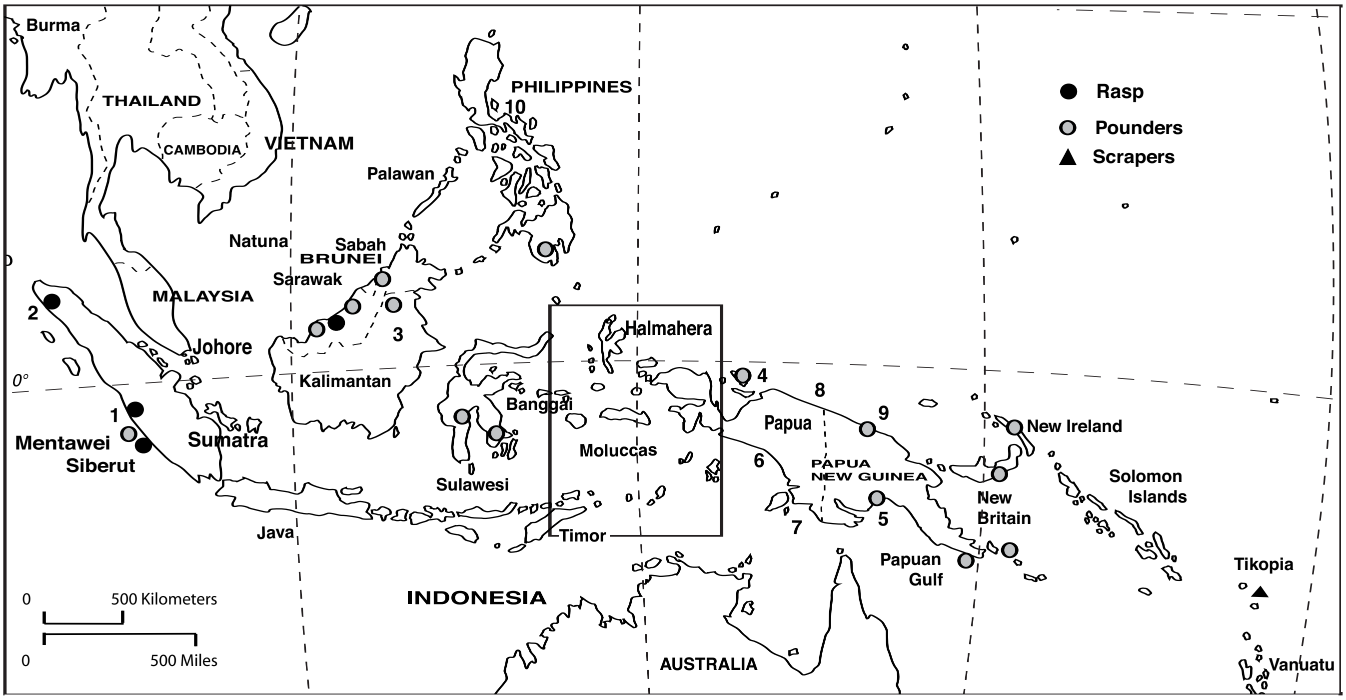
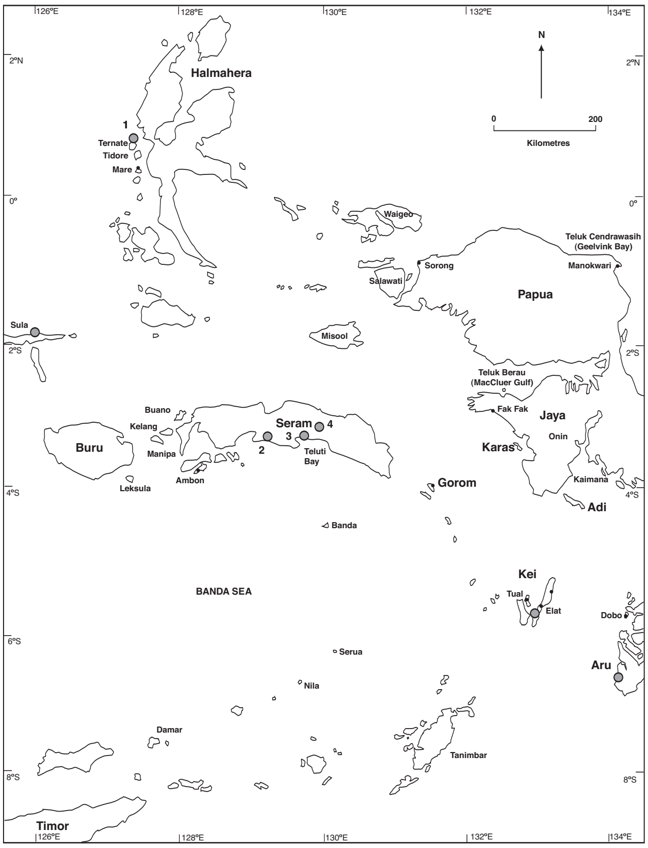


Figure 1. Indicative distribution of specialized sago pith extraction tools in southeast Asia and the Pacific, based on data reported in text. The lower figure illustrates in more detail the boxed area in the upper. Numbered locations are as follows: Upper figure: 1. Pasar Usang; 2. Sommelier; 3. Penan Benalui; 4. Bisnik, Biak; 5. Kikori; 6. Mimika; 7. Merauke; 8. Jayapura, Lake Sentani and Humboldt Bay; 9. Abelam, Sepik; 10. Cavite, Luzon;
Lower figure: 1. Toloko, Ternate; 2. Nuaulu, South Seram; 3. Hatumetan, Teluti Bay; 4. Piliana and Manusela, Central Seram.



type from south Seram (Figure 6) are rare, and the whole can be reinforced or not with a rattan piece across the angle, with a metal ferrule on the end of the blade. They are made mainly of *Intsia bijuga*, but also from *Lansium domesticum* and *Shorea selanica*. They were unusual in the Nuaulu area between 1970 and 2003, and I only saw one for the first time in 1996. They are reckoned to be longer-lasting than the bamboo pounder, but not as effective, nor as common. Pounders of this basic design are reported for Mentawai (off the west coast of Sumatra), Aru, Seram and the Mimika (e.g. RMV 1971–471, RMV 1889–199) and Asmat (RMV 4476–4) areas of southwest New Guinea, and for Lake Sentani (RMV 5875–11) in northwestern New Guinea, where they traditionally exhibit concave-ended polished stone heads.

3. A third type is made entirely of bamboo or has a bamboo head and wooden handle, where the head is inserted into the end of the handle and held in tension with rattan. This type has a much more restricted distribution. It is typical of many parts of the west central Moluccas, including Seram (Figure 7; also Ellen 2004b), Sula (Figure 8), Buru (RMV 1971–196) and possibly also parts of Halmahera (RMV 370-2198).

4. A fourth type also consists of two parts, head and elbow-shaped handle, though with a hafting formed by lashing the head against the elbow of the handle, with or without

lugs. Pounders of this type are always made of wood (Figures 9, 10 and 11), or wood and stone. A similar pounder is recorded for the Penan Benalui of East Kalimantan, where *Eugeissona utilis* is the most important species for starch extraction (Puri: personal communication). Other pounders of this general construction are known from museum collections for the north coast of western New Guinea (RMV 2027–146), including Memberamo (RMV 1971–1000a, 1971–1001), and for the Sepik (RMV 1863–163).

5. Although first appearances might suggest otherwise, the distinctive 'weti manano' pounder from parts of east and central Seram (Figure 12) is a structural variant of type 4. I have specimens and photographic records of this type from Hatumeten on Teluti Bay. The shaft and handle is of *Tectona grandis* ('kayu besi'), 79.5cm long with a metal ferrule and blade (Ellen, field notes: 75-01-53). A second example was recorded from Dai on the island of Gorom (Ellen, field notes: 86-16-24). The type has a restricted distribution and for this reason is most likely to have been a local adaptation. Its advantage over other types is its resilience, and perhaps ergonomic properties. A Nuaulu bamboo pounder (Ellen 2004b) will last two or three palms, while the 'weti manano' will last many years.

Figure 2. (above) Pounder (Höpfner 1977: 44, plate 11) made from single piece of hard wood, blade length 37 cm, south Seram, before 1889 (Ethnologisches Museum, Berlin: Ic. 22406); (below) Pounder made from flexed piece of bamboo held in place with rattan, blade length 32cm (Ethnologisches Museum, Berlin: Ic. 22294), South Seram, collected before 1889.

6. A sixth and final basic structural form is much rarer, where a head is hafted into a split handle, a form recorded in New Guinea for Teluk Berau (McCluer Gulf) (RMV 1971–1133), along the northwestern coast (RMV 1904–605) as far as Humboldt Bay (RMV 1904–603), for the Papuan Gulf (Figure 13), Halmahera (RMV 1106–57), the Kei islands (Figure 14) and Mindanao (Fernandez and Lynch 1972:298).

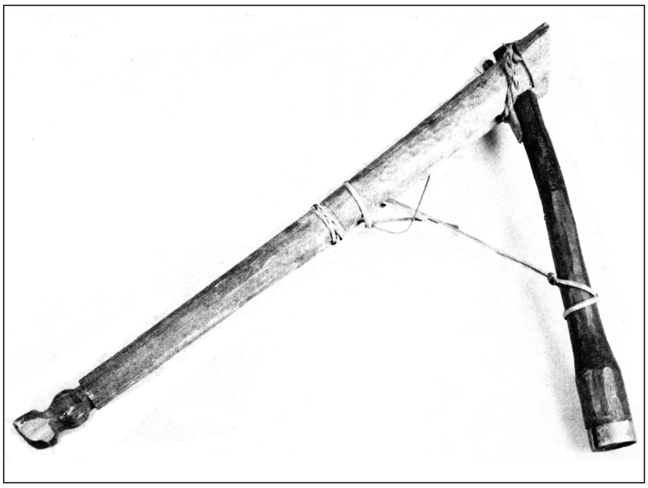


Figure 3. Pounder with blade and handle of two different woods, with metal ferrule (diameter 4cm), Aru islands, collected before 1913 (Höpfner 1977: 44, plate 15).

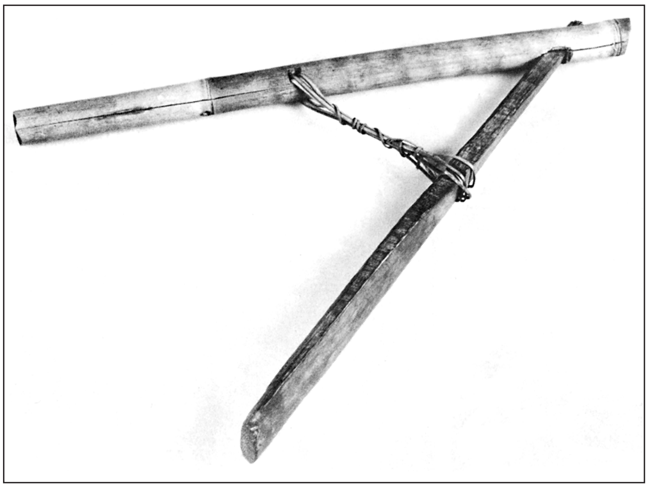


Figure 4. Pounder blade made from *Oncosperma tigillarium* palm wood inserted in bamboo, with rattan fastenings, blade length 52 cm, Mentawai islands 1897 (Höpfner 1977: 44, plate 10).

There are other dimensions of variation. In Tolaki, southeast Sulawesi, pounder heads were made of *Intsia bijuga*, with a handle of any wood (Figure 5). Beccari (1986 [1904]: 287) reports pounders from Bintulu, Borneo, usually slightly hollowed at the working end, while Morris (1953: 25) says that Melanau used wooden pointed adzes prior to

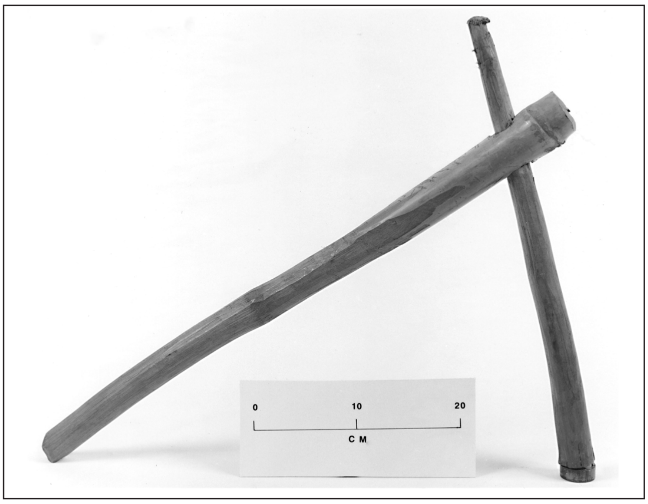


Figure 5. Pounder made of hardwood blade with metal ferrule inserted in bamboo handle, 1976, Tolaki, southeast Sulawesi (photo: Ellen 2001-01-04, Ethnobiol. Lab. UKC).

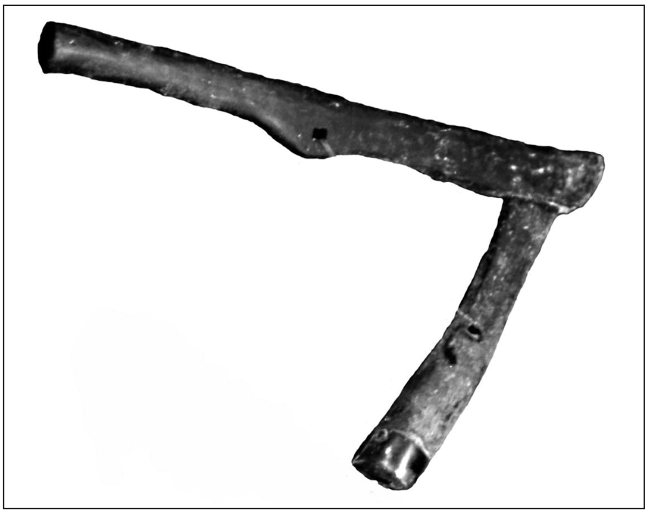


Figure 6. Pounders made entirely from *Intsia bijuga* wood with metal; ferrule and optional flexed rattan, Nuaulu, Upa valley 1996 (photo: Ellen 1996-17-03).

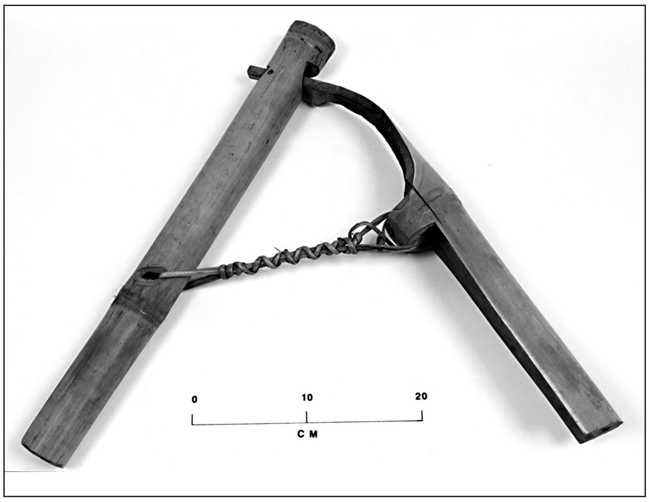


Figure 7. Pounder made from bamboo of different sizes fastened with rattan tensioner, blade length 48 cm, Nuaulu, 1970, Ethnobiol. Lab. UKC (photo: Ellen 2001-03-15) (also British Museum 1972 As.1.79; and cf. Berlin Ethnologisches Museum specimen: fastened with string (handle length 57cm, curved blade length 39cm), Seram 1882 (Höpfner 1977: 44, plate 12).

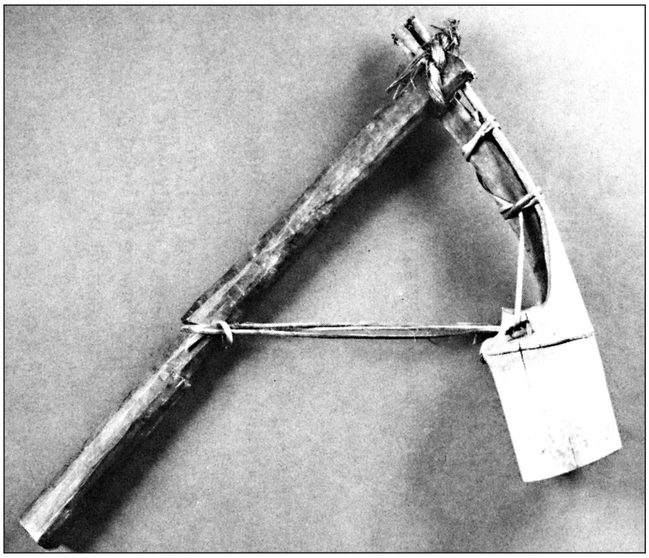


Figure 8. Pounder made of round bamboo blade and notched wooden handle (9cm wide at tip) with tensioner, Sula islands, 1889 (Höpfner 1977: 44, plate 13).

the introduction of nail-studded boards. Wooden pounders, as we have already seen, often incorporate pieces of iron, particularly as ferrules, and this is generally reported from parts of New Guinea, the Moluccas and Sulawesi (for example in the Toraja area). Occasionally, pounders are found which appear to be of a construction quite unrelated to more generic types, such as that shown from Brunei in Figure 14; or with the handle inserted into the head: Damar in the Moluccas (RMV 1241-261) or Kayan, East Kalimantan (RMV 1219–78). Different species of palm may require different pounders and different modes of action. *Arenga* pith, for example, is harder than *Metroxylon*, and in Cavite province in the Philippines the trunk of *Arenga* is cut into small pieces before pounding to a coarse meal (Ruddle *et al*. 1978:19). And, finally, some contemporary pounders (Figure 13) still incorporate stone working edges, a matter I shall explore in the next section.

Rasps (or *graters*) are reported mainly from the western part of the archipelago. These vary from short rasps no longer than 60cm and designed for use by a single person (Figure 17), to large reinforced boards studded with nails and operated by two people (Figure 18), as found in Pasar Usang, West Sumatra (Ellen 1985: field data), and on Siberut (Whitten and Whitten 1981). As a means of reducing solid pith to pulverized matter suitable for pressing, this

Figure 9. Pounder made of hardwood T-shaped handle and blade with metal ferrule, fastened with rattan; Samboru, Gorom 1986 (photo: Ellen 2001-01-01).

Figure 10. Pounder made from two pieces of same hardwood bound with rattan and with serrated iron ferrule; Bisnik, Biak, Papua/Irian Jaya 1990 (photo: Ellen 2001-01-03).

Figure 11. Pounder from Toloko, Ternate, 1990 (photo: Ellen 1990-01-08).

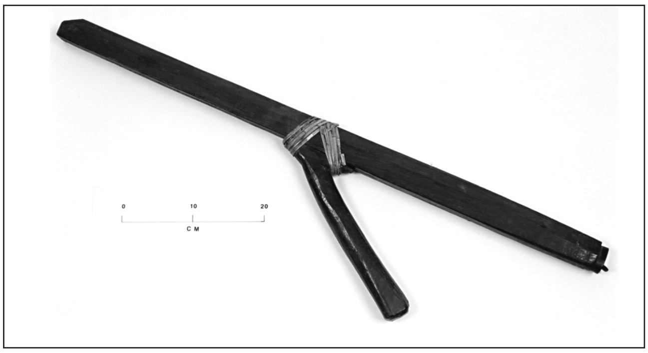


Figure 12. Pounder (the so-called 'weti manano') made of hardwood, with T-shaped handle and metal ferrule and cutting edge inserted at tip, Hatumeten 1975 (photo: Ellen 2001-03-11, Ethnobiol. Lab. UKC). This is similar in construction to a pounder collected on Gorom in 1889, with a handle and 68 cm blade made from separate pieces of wood tied together with rattan, and with a small sharp stone inserted in the tip (Höpfner 1977: 44, plate 14).

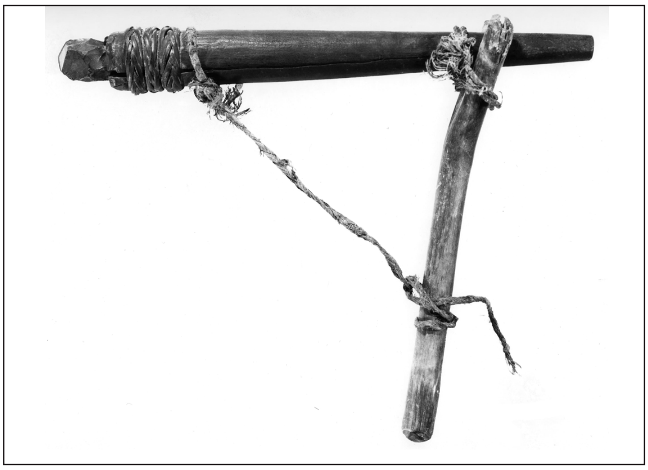


Figure 13. Stone headed pounder with split handle, Siligi Valley, Gulf Province, Papua New Guinea (photo: Rhoads 1980: plate III-9).

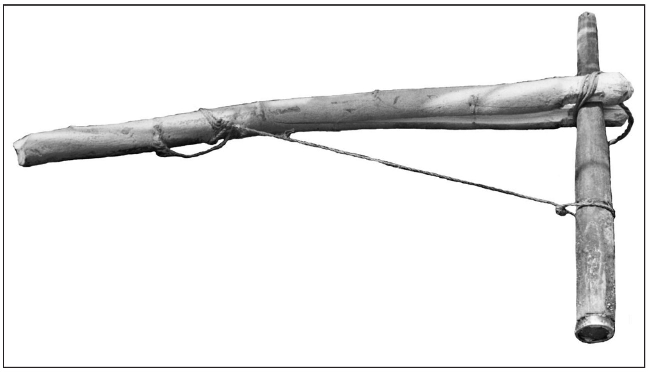


Figure 14. Pounder made of split wooden handle with hardwood blade and iron ferrule tensed with string, Raroreng, Kei Bear, 1981 (photo: Ellen 1981-11-26)

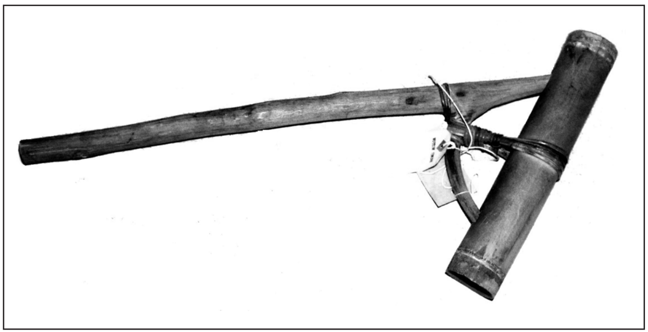
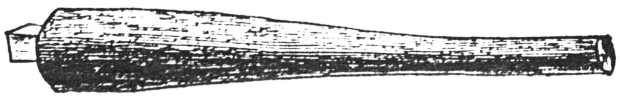


Figure 15. Bamboo pounder, no provenance, Brunei Museum 1974-114 (photo: Ellen 1994-02-08).



Sago Club

Figure 16. 'Club' of hardwood and quartz, east Seram in 1860 (Wallace 1962 [1869]: 290)).

Figure 17. Rasp from Sommelier, northwest Sumatra, L 62 cm, W 2-6cm. Ethnologisches Museum, Berlin (illustrated in Höpfner 1977: 22, plate 1).

Figure 18. Two person rasp, west Sumatra (photo: Ellen 1985-08-01).

method is more cost-effective than hand-held pounders, though the technique is only possible where the bark has been first completely removed. In small-scale operations, and where rivers are not available for transport, rasping may take place at the point where the palm is felled. Elsewhere, as Beccari (1986 [1904]:288) reports for the Melanau of Sarawak, trunks may be floated down river to be rasped in special sheds.

The geographic distribution of sago pith extraction tools is illustrated in Figure 1. At the present time, pounders are found mainly in the eastern part of the sago extraction range, and rasps in the west. The distribution of types of pounder shows a great deal of variability, even within a small area, with evidence that design variants may be used within a single population (i.e. Nuaulu evidence, but see also Klappa 2005: plate 4). This is what we might expect for a tool that is a simple adaptation of a basic axe/adze archaeotype, which itself displays a variety of hafting methods and combination of materials. Despite this shared archaeotype for elbow-jointed tools, and some cross utilization and hybridization of wood-working and sago-pounding tools, as Crosby (1976: 144, 148) has shown, wood-working and sago-pounding involve different combinations of function, often reflected in the use of distinct kinds of implement.

The distribution of rasps and pounders overlaps in the western part of the range, and in places (for example, parts of Sarawak and Brunei) rasps have replaced pounders (Figure 1), to some extent as a consequence of the commercialization of production. The machine graters now found in parts of the Moluccas, New Guinea and Malaysia, are an extension of this basic principle.

Archaeological evidence

Having reviewed the comparative ethnography of one kind of processing equipment in relation to pith removal, we can finally turn to the rather limited archaeological and historical data, in order to examine how far existing theories of the spread and evolution of starch palm technology (particularly with respect to *Metroxylon*) need to be modified.

We know little of the archaeology of Sahul before 30,000 BP, and there is no evidence of Pleistocene palm starch extraction (Yen 1995:837). Direct evidence for the extraction of palm starch is always going to be difficult to find because the preservation of plant remains from prehistoric deposits in the humid tropics is notoriously poor. Moreover, it is common to extract pith before the palm flowers, which reduces the likelihood of finding fossilized pollen, and therefore of reliable palaeobotanical dating (Rhoads 1977:33). We now, however, have identifiable palm starch residues from one site (Barton 2005), and there are strong reasons – based on the phytogeographic and ecological picture – for hypothesizing palm starch extraction (though not necessarily from *Metroxylon*) as part of the subsistence strategy of the earliest people in Sahul, and to a lesser extent Sunda.

Apart from starch residues, direct evidence is restricted to stone and ceramic artifacts associated with sago extraction and preparation. We know from the ethnographic evidence for *Metroxylon* processing that in many areas the palm itself provides material for equipment at all stages of processing (Ellen 2004b), including the containers used for cooking. Pottery is, therefore, not necessary, and less likely to be found. Here I am concerned only with stone artifacts.

In New Guinea, stone pounder heads (Figure 13), often though not exclusively cylindrical or conical with concave working ends, are reported widely between 1915 and the 1970s: from Teluk Cendrawasih (Geelvink Bay), along the northwestern coast (RMV 2970–1568) as far as Humboldt Bay (RMV 602–144, 132, 1904–327, 1904–606) and Lake Sentani (RMV 1356–2, and RMV 5875–11 respectively); the Sepik generally, on Huon Gulf (Hopoi), Collingwood Bay, as far east as the Massim (including Sanaroa and Dobu); and back along the south coast eastwards, via Mailu, the Papuan Gulf (including Kiwai and Kutubu on the southern fringes of the Highlands) to Merauke. These include roughly-shaped or naturally-occurring pieces inserted in old woodworking tools, and sometimes old wood-working blades hafted in slightly different handles; stone tools flaked to an elongated cone with a flat striking head or circular-sectioned, dimple-ended, stone heads hafted in the usual wood-working handle; and an implement made from a wooden handle and head in tension with stone blades inserted in the head (Crosby 1976: 146–8; Rhoads 1980; Figure 13 here; also P. White, personal communication). In addition, a number of New Guinea populations use stone tools to chop down sago palms. A cigar or bullet shaped sago palm feller, made from hammer-dressed igneous rock, and with no alternative uses (Figure 19), has a distribution coterminous with sago production areas (Crosby 1976, Rhoads 1977:32).

Similar reports on the use of stone heads also exist for central Borneo well into the late twentieth century (Avé 1977:23). Round sharp-cornered stones set in a bamboo head were once used in central and eastern Seram (Tauern 1918:103), and stone-headed pounders were reported by people in Manusela and Piliana in central Seram as having been used within their lifetime when I visited in 1975. Wallace reports quartzite heads in east Seram (Figure 16), although his (1962 [1860]:290) description and illustration of a sago 'club' of hard and heavy wood is an implausible shape ergonomically, and we only have Wallace's sketch to go on.

The unambiguous report of similar stone heads from well-defined archaeological contexts is, however, rare. Rhoads (1977:36; 1980:143, VI–22), working at a Kikori river basin site, found several chipped stone pounders with use polish still present (Figure 20), probably datable to 1500 BP. He notes (1977:35) that use wear patterns of all sago pounders obtained in ethnographic contexts are identical regardless of the stone used, a heavy silica gloss building up following persistent use; a distinctive trait which cannot be attributed to any other type of tool known from New Guinea. Artefactual traces of pith extraction further west are more-or-less non-existent. Burnished stone flakes found on Seram (Glover and Ellen 1975, Ellen and Glover 1979) may plausibly be, in some cases, from sago pounders, But apart from the repeat sporadic mentions of stone being used for sago pounders in ethnographic descriptions there is little more that can be said about the archaeology of this technology at the present time.

Figure 19. Specialized palm-felling tool, Sepik, Papua New Guinea (Rhoads 1977: 34, plate 1, photo E. Crosby).

Figure 20. Prehistoric pith-chopping stone showing use polish, from a site near Kopi village in the Kikori River basin, Gulf Province, Papua New Guinea (Rhoads 1977:36).

Discussion and Conclusions

On the basis of the comparative ethnographic, historical and archaeological evidence for pith extraction technology reviewed here we can draw a number of inferences about origins and modifications of tools used at the present time. The first two are quite specific and refer broadly to the period, approximately 1500-2000 years ago, when iron was becoming more readily available in eastern archipelagic southeast Asia for the material culture of basic subsistence.

1. That stone pounders and wooden and bamboo pounders with stone working edges have in some locations been superseded by wooden (including bamboo) pounders or wooden pounders with iron parts. This has happened, for example, on Seram since the mid-nineteenth century, with the addition of metal ferrules and in some cases the replacement of a stone flake with a metal working edge (Figure 12). This claim is based on oral tradition, the evidence of re-used stones as strike-a-lights and unstratified surface finds, and the testament of Wallace (1962 [1869]: 290). In New Guinea, the pre-European spread of iron eastwards from before 1606 (Kamma and Kooijman 1973:9) may have allowed some stone tools to be replaced by iron parts from quite early, though in Papua New Guinea stone headed tools are reported as being used down to the present.
2. That rasps used in Sumatra and Borneo, which require the insertion of many nails, were presumably preceded by pounders with non-metal parts, of the kinds described here for these areas. There is no archaeological or ethnographic evidence for rasps with non-metal parts, or close plausible analogies. We know of no use of metal in this way before the European period, and it is most likely that the rasp is no older than the eighteenth century (made using ships' nails) or even the nineteenth century. It might also be linked to the commercialization of sago-production, especially in Sarawak, perhaps under Chinese influence. Though rasps could be made using stone technology, we know of no helpful parallels in the lithic traditions of island southeast Asia.

Claims concerning the more ancient origins of pounders are grounded in the distribution of ethnographic reports on the relationship between wood-working and sago-working tools. Thus, we can draw a distinction on the island of New Guinea between extraction technologies used northeast of a line drawn approximately from Vanimo on the north coast to near Yule Island in the Gulf of Papua, and those to the southwest, with some hybridization of types along the northern boundary (Crosby 1976:149, 152; Klappa, 2005:408–9). Northeastern technologies largely involve wood-working implements adapted for pounding sago, while southwestern implements are generally specially constructed, except for isolates on the west coast of Teluk Cendrawasih and the Kiwai area of the Fly River delta. For Crosby, this suggests that the northeastern technology is indigenous to New Guinea, while the southwestern technology may have diffused from eastern Indonesia. As it happens, the evidence of eastward movement of other elements in the Moluccan sago technology complex (Swadling 1996), and the fact that the stone-metal transition for wood working tools was historically much earlier in Indonesia compared with New Guinea, is consistent with this hypothesis. Since sago pounding and wood-working tools are mechanically similar, and in New Guinea may overlap, and since ground edge axe/adze blades are known from 10,000 BP (Golson 2005: 466-9) and waisted blades from between 25,000 and 40,000 BP (e.g. Bulmer 2005:440; Golson 2001:196–7; Groube *et al*. 1986), sago use could plausibly be of similar antiquity. This would be consistent with the starch residue, botanical and ethnobotanical data described earlier.

Overall, the distributions of, and similarities between, pith extraction tools pose no particular puzzle in terms of cognitive propensity or comparative technology studies, as they exemplify a form widely found throughout the world, which might be described as the adze/axe archaeotype, utilizing structural principles (e.g. types of hafting) and working patterns easily transferred through analogy. What is clear though, even from a rather limited data set, is that with regard to the tools used to extract palm starch in island Southeast Asia and New Guinea, different elements are invented, borrowed from existing equipment, diffuse separately and are re-combined in different ways. Thus, materials (whether wood, bamboo or some mixture) may hybridize with different methods of hafting, where availability of resources permit. For this reason, we should not take distribution maps of specific variants too literally, as several forms can co-exist in the same place at the same time (as indeed is the case on Seram at the present time), or can be independently invented at opposite ends of the archipelago.

These data and the interpretations I have placed upon them are consistent with conclusions drawn with respect to other elements of the extraction and processing technology associated with starch palms in Southeast Asia and the Pacific, predominantly, though not exclusively *Metroxylon sagu* (Ellen 2004a), and suggest the need for more nuanced explanations. What an earlier generation might have seen in terms of regional or even global diffusion is much better understood in the first instance as a process of cultural selection involving local decisions as to how best to solve technical problems and how best to modify and improve those solutions over time as circumstances stabilize or change. An understanding of this process of cultural selection must take into account: (a) the broader technical repertoire available to individual populations; (b) a population's ability to adapt and develop equipment intra-culturally across techno-cognitive domains, drawing on a combination of local models; (c) a propensity to vary materials as availability necessitates, and (d) to repeatedly work things out from first principles on the basis of common human frameworks of intuitive physics informed by cultural and ecological experience, borrowing new ideas in part or in their entirety as appropriate. Thus, the data I have presented support the skeptical position taken by Sigaut on the confidence we should place in simple 'technical lineage' models, and teach us that old anthropological controversies about diffusion need to be occasionally revisited less we incline to an understandable fall-back assumption that all significant innovation must be exogenous.

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