ETHNO-ARCHAEOLOGY AND EARLY AUSTRONESIAN FISHING STRATEGIES IN NEAR-SHORE ENVIRONMENTS

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The past three decades of archaeological investigation and zoo-archaeological analyses of fish and shellfish remains in Oceania and Island Southeast Asia have revealed that early prehistoric Austronesian fishing was mainly practiced in inshore and coral-reef environments, especially during the first era of migration (about 3500 to 2500 BP) between Island Southeast Asia and Oceania.

In Oceania, faunal assemblages show that the major portion of the fish yield at Lapita sites was from inshore biotopes (Butler 1988, 1994; Green 1979, 1986; Kirch 1988, 1997, 2000; Kirch and Dye 1979; Kirch and Yen 1982). Yet Lapita people also exploited near-shore or off-shore marine environments using a variety of fishing methods, including angling and trolling (Butler 1994; Green 1986; Kirch 1997, 2000; Walter 1989). Later, when people colonised islands with limited coastal resources—mainly in Polynesia and Micronesia—angling and trolling technologies were further developed or became more intensively used (Davidson *et al.* 1999, Intoh and Ono 2007, Kirch and Dye 1979, Leach and Davidson 1988, Leach *et al.* 1988, Ono and Intoh in press, Rolett 1989).

Similarly, faunal assemblages from Neolithic sites in Island Southeast Asia, which were contemporary with Lapita sites, clearly indicate that inshore and coastal biotopes were intensively exploited (Bautista pers. comm. 2002; Ono 2003, 2004). However, unlike the findings in Lapita sites, no fishing tools (e.g., hook, net sinker or lure) have been found[1] and the numbers of pelagic fish bones (e.g., tuna) are few in Island Southeast Asia Neolithic sites. Certainly there are few archaeological sites with well preserved marine fauna dated to the early stages of Austronesian migration in the Island Southeast Asian region, and their evidence indicates that early Austronesian fishing tended to be focused on the inshore biotopes.

Walter (1989: 138) attempted to elucidate the Lapita fishing strategies through an examination of linguistic evidence and suggested that angling techniques were one of major methods used by early Oceanic speakers, including Lapita people. Butler (1994) examined the relationship between fish feeding behaviour and human predation strategies and argued that evidence from some Lapita sites suggested both angling and netting were commonly practiced. Moreover, fish hooks, lures, and possible net sinkers have been excavated from some Lapita sites (Bedford, pers. comm. 2009; Butler 1994; Kirch 1997, 2000; Kirch and Dye 1979; Summerhayes 2007; Szabo and Summerhayes 2002). Thus, both archaeological and linguistic evidence support the use of angling, netting and trolling by early Oceanic speakers. Yet, no fish hooks, lures or possible net sinkers have been excavated from the Neolithic sites in Island Southeast Asia except two fish hooks from East Timor (Glover 1986: 97-119).

The problem posed by the archaeological record can perhaps be resolved by comparing the results of zoo-archaeological fish bone analysis with ethno-archaeology research focusing on fish capture to infer prehistoric practices. I undertake in this article (i) to provide quantitative ethno-archaeological data for contemporary inshore fishing in a shallow coral reef environment to provide further comparisons with archaeological fish bone data, and (ii) to discuss and reconstruct fishing strategies employed by the early Austronesian-speaking populations in Island Southeast Asia and Oceania.

Ethno-archaeological studies of contemporary fishing in Oceania were initiated by Kirch (1976) in Futuna and Uvea, Kaschiko (1976) in the Solomon Islands and Kirch and Dye in Niuatoputapu (Dye 1983, Kirch and Dye 1979) to collect information on the fishing activity in Oceania. These studies were significant in demonstrating the importance and potential of this novel approach to archaeological studies. However, limitations and problems remained, including a lack of quantitative data on labour and time input associated with marine exploitation, and the consequent yield outputs (Kirch and Dye 1979: 74).

From the 1980s, ethno-archaeological studies of contemporary fishing increased: for example, Chikamori (1988) in Rennell, Goto (1988, 1990) in Hawai‘i and the Solomon Islands (Goto 1996), Masse (1986, 1989) in Palau, Kataoka (1991) in Pohnpei and Rolett (1989) in Marquesas. These studies have broadened our knowledge of alternative behaviours associated with fishing in Oceania; however, in quantitative terms, the fishing activities observed or recorded by most of these studies were still limited in number.

To rectify the paucity of ethnological quantitative data on inshore fishing and shellfish gathering, and also to provide a basis for a more robust reconstruction of the early Austronesian fishing activities and strategies mainly practiced in inshore environments, I undertook intensive ethno-archaeological investigation among the Austronesian-speaking Sama on the eastern coast of Borneo Island, whose fishing is mostly inshore.

First, I describe the general character of contemporary Sama fishing and detail 101 recorded events of fishing and gathering activities, discussing (i) the general character of the fishing in terms of the seasonal and tidal cycle, and (ii) the correlation between each fishing method and captured fish varieties, sizes and fishing grounds. Then, drawing on this quantitative data and ethno-archaeological research, I undertake a reconstruction of early Austronesian fishing activities and strategies in inshore environments.

LOCALITY AND THE SAMA PEOPLE

My research was conducted in the Semporna district on the east coast of Sabah State, Malaysia. This district includes the lowland Semporna Peninsula surrounded by widely developed coral reefs (Fig. 1), on the tip of which the well-known Neolithic site, Bukit Tengkorak, is located. This site produced numerous potsherds and stone tools, and abundant faunal remains, including pig, fish, shellfish and sea turtle dating back to 3,500 to 2,000 BP (Bellwood 1989; Chia 1997, 2001, 2003; Ono 2003, 2004, 2006). The site is remarkable for its obsidian tools, many of them made of Talasea obsidian sourced to New Britain, which is approximately 5,000km from Borneo (Bellwood and Koon 1989; Chia 1997, 2003). This raises the possibility that Bukit Tengkorak was inhabited by Austronesian-speaking populations who had a direct or indirect relationship to Austronesian-speaking groups in Oceania, perhaps to the Lapita people.

The 70,000 Sama or Bajau people are the major population of the Semporna Peninsula, making up over 90 percent of the total population. Their language falls within the Western Malayo-Polynesian language group of the Austronesian language family (Pallesen 1985, Sather 1997), and they are probably the most widely-dispersed ethno-linguistic group indigenous to Island Southeast Asia. Major settlements of Sama speakers extend from eastern Palawan and the Sulu Archipelago in the Philippines to the eastern coast of Borneo, southward to Sulawesi and from there over widely-scattered areas of eastern Indonesia, south and eastward to Flores and the southern Maluku (see Sather 1997, Sopher 1965).

From the 18th to the 19th centuries Sama speakers were renowned for their sea-based subsistence and boat-dwelling lifestyle, and were frequently referred to as "sea gypsies" in European literature. Nothing is known directly about the Sama before the early 16th and 17th centuries. Linguistic reconstruction suggests that the Sama-Bajau languages can be traced only to the first millennium AD. By about AD 800 speakers of Proto Sama-Bajau are thought to have lived in the northern islands of the Sulu Archipelago and along the adjacent Mindanao coastlines bordering the Basilan Straits. The reconstructed lexicon points to a long-standing familiarity with farming, iron-forging, pottery-making and weaving, as well as with fishing and seafaring (Pallesen 1985: 118).

Even in the 18th to the 19th centuries, Sama-Bajau speakers were not just a single group engaged in full-time fishing as boat dwellers (Warren 1971:

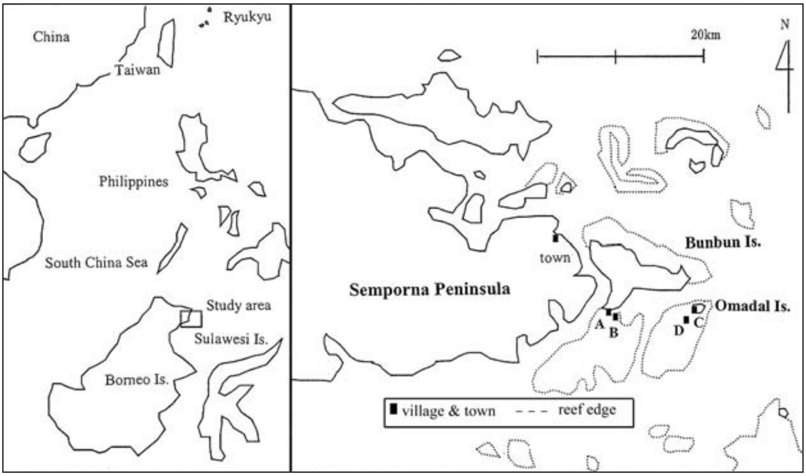

Figure 1. Borneo Island and the Semporna Peninsula.

xiii). Within the social and economic structure of the Sulu Sultanate, Sama society was composed of two main groups identified as *Samal* or "Land Sama" (*Sama Deyak*) and "Sea Sama" (*Sama Dilaut*). Land Sama were settled villagers forming a social middle class, engaged in farming, trade, boat building, pirate activities and fishing. The Sea Sama, whose social status was the lowest within the Sulu Sultanate, were mostly engaged in fishing as nomadic boat dwellers.

By the end of the Second World War and with the emergence of new nations in the region, most Sama had started living in stilt houses on coral terraces or island coasts along the eastern coast of Borneo. Their lifestyle and subsistence changed rapidly from the 19th century, but they still form two main groups: the Land Sama, who are Malaysian citizens, are the dominant population and are engaged in a variety of economic activities—farming, fishing, trade and salaried work; and the Sea Sama, who remain a minor population in the region, are considered illegal trespassers and mainly inhabit remote islands in the district.

Among the Sama groups in the Semporna District, I surveyed four villages: two villages of Land Sama small scale fishermen and two villages of Sea Sama fishermen. The villages are located on the islands of Bunbun and Omadal, two of the remote islands that are surrounded by wide fringing coral reefs, located off the Semporna Peninsula.

The villages are labelled as follows (see Fig. 1): on Bunbun Island Village A (Land Sama) of 37 households (508 people) and Village B (Sea Sama) of only 8 households, on Omadel Island Village C (Land Sama) of 22 households (200 people) and Village D (Sea Sama) of more than 100 households. I could not establish the exact numbers of households or people in the Sea Sama villages because people were constantly moving in and out of the village, and in any case it was hard to visit each house without a boat. The houses are built in the middle of a coral reef and many villagers are absent fishing during the day. Because of these logistical limitations, I interviewed Sea Sama residents of Village B and D in a random fashion.

Both Land Sama villages have been notable fishing villages since the late 19th century, but my household survey revealed that the number of active fishermen was decreasing and some households had already shifted to alternative economic or subsistence activities. Seventeen households in the Village A (55%) were engaged in fishing while only 11 in Village C (40%) were. Among these 11 households in Village C, nine are also engaged in seaweed (*agar agar*) cultivation, a project initiated in the village by the state government in 1999. By contrast, all the Sea Sama households in both village B and D are engaged in small scale fishing and can be regarded as fulltime fishermen.

ETHNO-ARCHAEOLOGY AND METHODOLOGY

Gould (1978: 10) defined ethno-archaeology as "an empirical approach designed to discover the totality of variables that determine human behavior in particular situations and to posit general principles indicating how these variables consistently interact". Ethno-archaeology also offers "the opportunity to construct general ethnographic models linking marine biota, environment, technology and human behaviour that may allow for more rigorous control in the interpretation of archaeological data" (Kirch and Dye 1979: 55-56).

My fieldwork was conducted from November 2003 to March 2004, June 2004 and from November to December in 2004; a total of over 230 days. The research was designed to (i) characterise the marine environment in terms of spatial and temporal variability including species distribution patterns and tidal and seasonal changes; (ii) obtain data on the local understanding of the marine environment and resources that account for the rationale behind behavioural strategies; and (iii) observe and elicit data on the different aspects of fishing practices—material culture, organisation of effort, range of resources taken, and the distribution and subsequent consumption of the caught fish.

Data for (i) and (ii) were obtained through observation and ethnographic inquiry. I used participant observation, fixed point observation and ethnographic inquiry to acquire data for (iii). Participant observation offered the opportunity to become directly involved in fishing party organisation and catch distribution. I participated in 17 fishing expeditions and conducted interviews following 12 of them. Fixed point observation provided the quantitative data on total fishing time, total number of fishermen participating, major method employed, total catch (kg), captured species etc. These observations were recorded at the house of a fish buyer in the Land Sama village B for two extended periods. In the field, I mostly used Malay (*Bahasa Melayu*) without the aid of an interpreter, and Sama or Bajau languages (*Bahasa Sama*) were used when interviewing Sea Sama people with the assistance of a Land Sama interpreter.

GENERAL CHARACTER OF SAMA FISHING

Fishing in the shallow water of coral reefs is the most defining attribute of Sama fishing. People seldom fish on the outer reef, and no pelagic trolling or angling in deep water is recorded in accounts of Sama fishing methods (Table 1). The only exceptions are shark fishing with long lines (*laway*) or large hooks (*sngkaliya'*) with a bamboo rattle (*kuluk-kuluk*) that makes noise to attract sharks (Nagatsu 1995: 60), and sea turtle fishing with a two- or three-forked harpoon (*sahapang* or *salubang*) (Nagatsu 1995: 69). These two methods are the only ones Sama use in both the inner and outer reefs.

The Sama's shallow water fishing techniques in coral reefs exhibit marked characteristics indicative of their fishing methods and activities. First, net fishing of great variety is the primary method of fishing (Table 1). The people reason that netting captures a wider variety of fish in shallow coral reefs. Different methods of net fishing include using the *angalakod*, a type of gill net set in water channels at high tide by two to six fishermen who then attempt to guide fish into the net by dragging rattan ropes under water. *Angalingi'* is another type of gill net used by both the Sea Sama and Land Sama in shallow water to catch a range of fish. *Angambit* is the only large co-operative net fishing, which is jointly undertaken by 20 to 100 boats (Nagatsu 1995: 74-76, Sather 1997: 124-28). In Semporna Sather (1997: 127) observed this co-operative net fishing in the 1970s, but I did not encounter it nor has it been reported more recently. Nagatsu (1995: 76) commented that the popularisation of cheap and bigger nylon nets is one of the reasons for the drastic disappearance of co-operative fishing by large groups. These groups traditional used nets made from plant fibre which were time-consuming to produce and relatively small, requiring a significant number of people working together, deploying many nets, to catch a large quantity of fish.

Handline fishing (*ami'si*) is another major fishing method used both by the Land and Sea Sama in recent times. It only requires simple and low cost lines and hooks, and is easily pursued by all villagers—men, women and children. Night inshore trolling (*angaullan*) with a special lure to catch some species of squid (*kanuus*) is popular and usually practiced by a fishing group of two or three boats. Shark fishing with a long line is only done by a few Sea Sama fishermen. These trolling and long line fishing methods were introduced into Borneo quite late—the early 20th century and possibly after the 1940s.

Night spear fishing (*anu'*) to catch some coral fish (*daing batu*), rays (*pahi*) and sea cumbers (*bat*) is another popular fishing method. A coconut torch (*su'*) was used for *anu'* fishing in the past (Nagatsu 1995: 69), but kerosene lanterns were introduced as a light source shortly after the Second World War (Sather 1984: 18) and have been used ever since. People usually spear fish from the bow of a boat, illuminating the sea surface with a torch light. A variety of fish and octopus (*kuhita'*) are impaled with spear guns when diving with goggles. Poison (*anua'*), derived from the roots of *Derris* spp., is used to catch small school fish. For trap fishing, wooden weirs (*bunsud*) and rattan or metal wire baskets (*bubu*) are used. Shellfish (*siput*), sea urchin (*tehe'tehe'*), seaweed (*agar agar*) and sea cucumber, as well as some fish species (e.g., Diodontidae), are commonly gathered by women and children on the reef flats or tidal zones at low tide.

Besides these older and traditional fishing methods, some very new methods have been adopted by the Sama. These are dynamite fishing (*animbak*) and poison fishing with chemicals such as cyanide. Both methods were possibly introduced to Semporna by the early 1960s from the Philippines.[2] During the 1980s seaweed (*Eucheuma cottoni* and *E. spinosum*) cultivation was also introduced to the Semporna seas from the Philippines as a new form of marine exploitation. It is now under the control of a government programme (through the Fishery Department) and I observed it at Village C on Omadal Island. Aquaculture of live fish and crustaceans, such as grouper (*kohapo'*), a species of wrasse (*Ceilinus undulates* / *langkawit*) and lobster (*keyot*), has been introduced by Chinese Malaysians. Some Land Sama households have tried to keep and feed these highly valued fish in cages close to the village to sell at higher prices than those asked by aquaculture owners around the Semporna town. In most cases, Sea Sama fishermen are the main suppliers of these live fish.

A second notable feature of Sama fishing is the participation of women and children, not just gathering shellfish and sea urchins in tidal zones but also occasionally joining other fishing activities with adult men (Nagatsu 1995; Ono 2006, 2007; Sather 1997). One explanation for their participation is that most Sama fishing is practiced in shallow water where risks are minor and the work is not strenuous. For Sea Sama people, their traditional fishing and style of living in a house boat might be considered as another factor.

Table 1. Major Methods in Sama Fishing.

Method	Local Name	Group	No. of Fishers	Fishing Grounds	Fishing Time	Best Tide	Aimed Captures	Equipment(s)
Netting	*amahang*	Sea Sama	2-3 pers.	reef channels	night - morning	spring	inshore species	gill net with rope
	angalakod	Sea Sama	2-3 pers.	reef channels	day	ebb	inshore species	gill net with rope
	angalinggi‘	Both	2-3 pers.	lagoon/reef flat	night/morning	ebb	inshore species	gill net
	-	Both	1-2 pers.	lagoon/reef flat	night/morning	anytime	inshore species	gill net
	magselo	Sea Sama	2-3 pers.	lagoon/reef flat	night/morning	spring	Belonids	gill net
	anganbit	Sea Sama	50-100 pers.	lagoon/reef flat	day	ebb	inshore species	gill net
	amokot	Sea Sama	2-3 pers.	shallow reef flat	day	spring	inshore species	purse seine net
	pukat tunda	Land Sama	3-10 pers.	sand or mad bottom	day	anytime	bottom species	trawl net
	amungsud	Land Sama	1-2 pers.	lagoon/reef flat	7th-9th moon	ebb	Siganids	wooden weir
Angling	*amissi*	Both	1-2 pers.	lagoon/reef edge	evening/ morning	spring	Lethrinids/ Serranids/etc	hand line
	angullan	Both	2-5 pers.	lagoon/reef flat	night	full moon	squid	line with lure
	angalaway	Both	2-5 pers.	reef edge/outer reef	evening/ morning	anytime	sharks	long line
Spearing	*anu‘*	Both	1-3 pers.	reef flat	night	high	inshore species	spear
	magbat	Both	1-3 pers.	reef flat	night	low	sea cucumber	spear
	ahiyak pahi	Both	1-3 pers.	reef flat/outer reef	night	full moon	rays, stingray	spear, harpoon
	magkoha‘	Sea Sama	1-3 pers.	isolated corals	night	no moon	sea turtles	harpoon
Poisoning	*anua‘*	Both	1-2 pers.	shallow reef flat	day	high/low	Serranids, Ariids	plant poisoning
Basket trap	*bubu*	Both	1-2 pers.	reef flat/edge	a few days	anytime	bottom species	basket

Diving	*magpana‘*	Both	1-2 pers.	reef flat/edge	anytime	high/low	inshore species	spear gun, goggles
Trapping	*anahat*	Both	1-2 pers.	reef flat	day	spring	mantis shrimp	stick
Dynamiting	*animbak*	Both	1-2 pers.	reef flat/edge	day	high/low	inshore species	dynamite, glass bottle
Gathering	*magalai*	Both	1-5 pers.	reef flat	day	low	shells, sea urchins etc	hand
Cultivating	-	Land Sama	1-5 pers.	lagoon/reef flat	day	anytime		rope, plastic bottle
Aquaculture	-	Land Sama	1-3 pers.	lagoon/reef flat	anytime	anytime	Serranids, Labrids etc	nets, wood

Source: Ono interview surveys, Nagatsu 1995, Sather 1997.

The decline in the use of house boats brought a decrease in the frequency of women's fishing, but boys still occasionally join in men's fishing, especially among the Sea Sama.[3]

The third feature of Sama fishing is the small size of the boats and gear and the small number of fishermen engaged in each fishing activity. The rich variety of species and the number of rocky shallow reefs make small boats and gear more suited to fishing in coral seas. Large scale labour is not essential except in a few cases of seasonal community or co-operative fishing—such as *angambit* in the recent past. For these reasons, the number of fishermen involved in each fishing activity is small—basically one to three people.

Boats are essential for Sama fishing. There are several types. A wooden boat, known as a *lepa*, was locally built and used for a Sea Sama's house boat during most of the 20th century. By the 1990s these had largely been replaced by low cost plywood boats called *tempel*. Sather (1997: 133) pointed to the scarcity of large timber and increased monetary cost as the reason for the replacement of *lepa* with *tempel*. The *lepa* has a dugout canoe for the hull and a sharp and beautifully curved stern and bow. The *tempel* has no such elegance, having a flat stern for attaching a small inboard or outboard engine (5-15hp), suggesting that another reason behind this change was the advent of engines. Small inboard engines (*pambot*) were introduced to Semporna from the Philippines possibly during the 1950s and achieved widespread usage by the mid-1960s (Sather 1997: 116). Currently, Japanese- or American-made outboard engines are widely used.

The Sama also use small dugout canoes (*boggo*), but their numbers have been decreasing. These are for moving around villages or for line fishing close to villages and are often used by women and children. Double outrigger boats have seldom been used by the Sama in Semporna in recent times. They were more popular in the past before the *lepa* was invented (see Kuraris 1975, Monden 1986, Nimmo 1965, Spoehr 1971). Although it is unclear why the outrigger was abandoned, Monden (1986) suggested that the prevalence of net fishing in the recent past might be one of the reasons.

Sama employ many kinds of nets (e.g., *linggi'* and *selibut*), nylon lines (*tansi'*), spears (e.g., *pogol* and *selikit*), harpoons (e.g., *sangkil* and *bujak*) and metal hooks (*pissi*). As mentioned above, for making nets and lines some local plant fibres (e.g., *Ficus microcarpa*) were used before the 1920s. During the 1920s, manufactured cotton twine (*salban*) was introduced and quickly replaced locally-made cordage as a net-making material (Sather 1984: 18). Nylon had replaced cotton line by the 1970s (Sather 1997: 117). Nylon line is now also used for hand lines with metal hooks. Some form of goggles and spear guns (*pana*) were possibly introduced from the early 20th century. Baskets (*bubu*) made from rattan or metal wire are also used by some. Wooden fish weirs (*bunsud*) made from mangrove trees and trawl nets are currently popular, but only some Land Sama fishermen own and use this kind of weir as it takes up considerable space and requires permission to use coastal areas for its construction. The number of Land Sama fishermen who own *bunsud* is also limited because of the building and maintenance cost.

A final important feature of Sama fishing is its strong economic component. Since the 18th century, the place of the Sea Sama in the structure of the Sulu Sultanate has been as fulltime fisherfolk , while Land Sama have engaged in various economic or subsistence practices, including farming, trading, fishing and some pirating (Warren 1971). As soon as the Semporna market station was established in the late 19th century, the Sama (especially Sea Sama) began to sell their surplus catch as dried and salted fish through town shopkeepers and other dealers in local commodities (Sather 1997: 52, Warren 1971: 65). It is clear that Sama fishing is not only a subsistence endeavour providing the dominant source of protein in the local diet, but is also deeply involved in the market economy.

In general, there should be fundamental differences between modern and prehistoric fishing gear with respect to type, raw material composition and mobility. However, the function and the nature of each fishing method, in the past and present, should be essentially similar in respect to the main species captured, correlated fishing grounds and the effects of tidal or seasonal cycles. Hence the quantitative data collected on contemporary fishing practices, particularly focusing on the correlation between each major fishing method and captured species, fishing grounds and seasonality, including tidal and lunar cycles, are useful for understanding prehistoric fishing and therefore are important for the archaeological study. Although recent Sama fishing uses modern gear and is strongly influenced by a market economy, it is still worth observing and examining their fishing practices, particularly those as related to seasonality, and the relationship between each fishing method and the detail of major captures. The fact that the Sama fishing is mostly practiced in shallow coral reefs with relatively small and simple fishing gear and boats may also provide us opportunities to consider and reconstruct the inshore fishing of the past in greater detail than a reconstruction based solely on archaeological findings would provide.

SEASONAL AND TIDAL CYCLES

Sama fishing is attentive to tidal and seasonal cycles. The seasonal cycle in Semporna is basically characterised by the monsoon cycle. In the Celebes Sea including Semporna, the rather humid southwest monsoon comes from May to September and the much drier northeast monsoon blows from December to March. During the north-east monsoon season, much stronger winds tend to blow and this restricts Sama fishing, especially in the past when there were no engines to drive the boats.

The Sama termed the south-west monsoon season *musim satan* lit. 'south season' and the north-east season as *musim utala'* lit. 'north season', while the interval seasons between *musim satan* and *musim utala'* from October to December is called the 'western wind season' (*habagat*) and from March to May is called the 'no wind season' (*teddo'*) (Fig. 2). The *teddo' s*eason is widely recognised as the best season for fishing (Nagatsu 1995: 23). The direction and strength of wind are the main indicators of seasonal changes especially for fishing. Rainfall is not a major feature of the seasonal cycle in Semporna since there is no clear change in the amount of rainfall during a year.

The lunar cycle is crucial for the Sama fishing because it correlates with tidal changes, as shown in Figure 2 (see also Sather 1997: 97). Some Sama fishing is pursued in a particular moon phase, such as stingray spearing and squid angling around *t'llak bulan* 'full moon'.

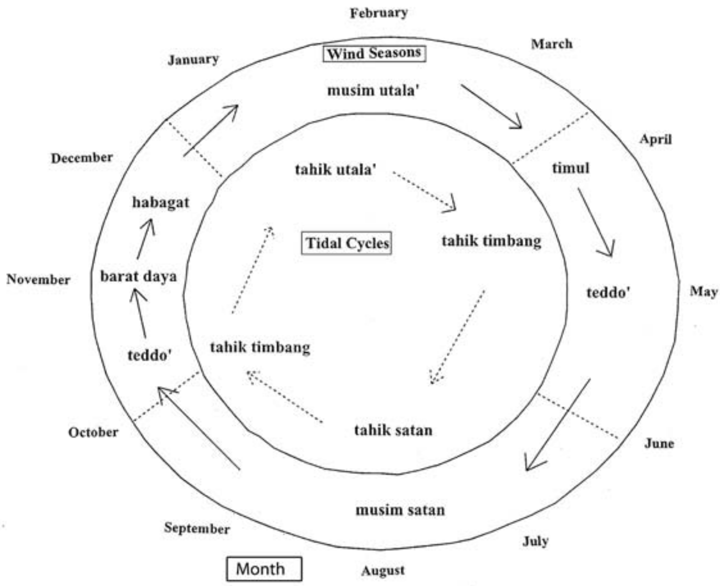

Figure 2. Annual and tidal cycles in Sama language.
(After Nagatsu 1995, Ono 2006, Sather 1997.)

The tidal changes do impact significantly on the Sama fishing on the coast and inshore seas. Both tide and sea water are called *tahik*. The daily tidal changes are classified as *alalom tahik* ‘high tide’, *lumaang* ‘ebbing tide’, *atoho‘t‘bba* ‘low tide’ and *anso‘* ‘rising tide’. Some fishing activities such as netting and angling are primarily conducted during ebbing (*lumaang*) and rising (*anos‘*) tides, while spearing and diving are practiced at maximum high tide (*balosok*/*alalom tahik*) or maximum low tide (*agot*/*atoho‘t‘bba*), and gathering is carried out only at low tide (see also Sather 1997: 100). Of the 85 events of net and hand line fishing recorded, 66 percent (n=56) were started during the ebbing tide, while 27 percent (n= 23) were started during the rising tide.

The monthly tidal cycle is divided into two phases: peak flood currents or *tahiheya* lit. ‘big tide’ and peak ebb tide or *tahik diki* lit. ‘small tide’. These two phases basically alternate within about seven days, so there are two *tahik heya* and *tahik diki* phases in a month. During the phase of *tahik heya* high tides come in the early morning and evening and during *tahik diki* they arrive around

Table 2. Correlation between some fishing activities and lunar/tidal cycle. (After Nagatsu 1995: 24.)

Name of Method	Aimed Capture	Particular Season(s)	Reason
ahiyak pahi	stingrays	*t‘llak bulan* (full moon)	wider sight at night
angullan	squid	*t‘llak bulan* (full moon)	lure needs light to shine
anahat	mantis shrimp	*tahik heya* (spring tide)	tide getting too low to find holes easily
anganbit	inshore species	*tahik diki‘* (ebb tide)	i.tide change is slow and it is easy to find fish ii.tide is low for ease of walking on reef with nets
amungsud	Siganids	7th-9th moon (April-October)	fish come to reef to spawn and return offshore
angak tehe-tehe‘	sea urchins	18th-20th moon (all year)	ovaries of sea urchin grow during this season
magselo	Belonids	20th-10th moon (all year)	when moon is bright, fish notice net and swim away
angalaway	sharks	March-April	sharks more easily caught in these months
magkoha‘	sea turtles	March-May	turtles visible in very calm sea with no waves

noon and midnight. Generally, more dramatic tidal changes (rise and fall) occur during *tahik heya* and Sama fishing activity increases during this phase. According to the Sama fishermen, fish more actively search for food during *tahik heya*, therefore it is much easier to catch them during this phase.

The tidal changes are also recognised as annual cycles corresponding to the monsoon cycle as shown in Figure 2, and the tide during *musim satan* is called *tahik satan*, while the one during *musim utala'* is called *tahik utala'*. As noted above, high tides come in the early morning and evening during *tahik heya*; the one in the morning is higher than the one at evening during *tahik satan*. The sea level in the evening gets higher during *tahik utala'*. Between these two monsoon seasons, the sea level at high tide is equal in morning and evening, and this tidal phase is called *tahik timbang* lit. 'balanced tide'.

In terms of the relationship between fishing methods employed by the Sama and tidal or lunar cycles, Nagatsu (1995: 24) listed some fishing activities by Sea Sama that clearly correlate with such natural cycles (see Table 2). All the evidence and his data introduced here clearly show that Sama fishing has been practiced under natural and marine environmental influences, including monsoons, lunar and tidal changes, and such characteristics were much stronger before the introduction and use of modern equipment (and engines).

RELATIONSHIP WITH MARINE ENVIRONMENTS

An important consideration for reconstructing prehistoric Austronesian fishing is in which specific marine environments each fishing activity and method is practiced. In Semporna, the Sama basic term for coral reef seas is *t'bba*, and they further classify the marine ecosystem into eight zones: (i) tidal coast with beach rock is *bihing deyak*, (ii) shallow lagoon is *halo*, (iii) tidal shallow reef flat is *diyata'kud*, (iv) a bit deeper reef flat is *b'ttong ambiyul*, (v) reef edge with visible bottom is *angan*,[4] and (vi) all deep seas over 10m in depth is *s'llang* (Nagatsu 1995, 1997; Sather 1997).

The coral seas around the research villages have wide sandy tidal zones, reef flats and are part of a rather deep reef lagoon (Fig. 3). The reef flat formed between the southern coast of Bumbum Island and Karindingan Island is the largest, with a sandy bottom where seaweeds grow. By contrast, the coral reef that has formed around Omadal Island has a much greater depth of water with more corals and a sandy bottom. Some reef lagoons with less than 5m depth of water are also formed in the reef and these biotopes are given individual names by the Sama fishermen and acknowledged to be good fishing grounds (see Fig. 3). Between the coral reef around Karindingan Island and another coral reef around Omadal Island, a deeper water channel formed (10 to 20m in depth). Another similar water channel is located between the coral reef

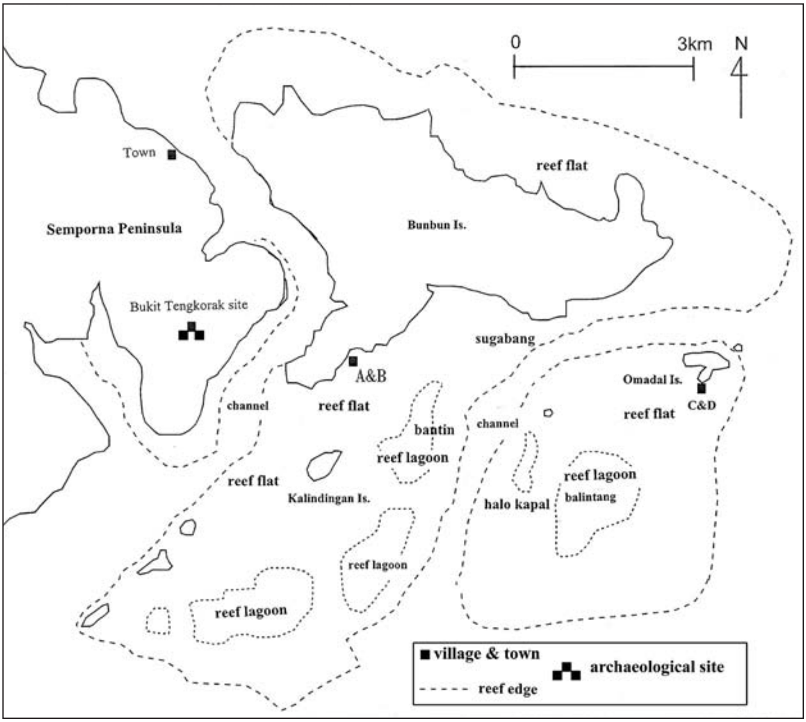

Figure 3. Micro-environments and major fishing grounds in study area.

around Karindingan Island and the coast of the Semporna Peninsula. These channels are classified as 'outer reef' (*s'llang*) and commonly used for angling, although they are not the major fishing ground.

Figure 4 shows the distribution of the major fishing strategies in relation to a generalised cross-section of Semporna's marine environment as the Sama classify it. It is obvious that most of the Sama fishing, netting and spearing is pursued in the coral sea zone (*t'bba*), particularly in the reef flat (*diyata'kud*) and shallow lagoon (*halo*) zones. Angling is the major method of fishing in deeper water, mainly around reef edges such as *angan,* but the frequency of Sama fishing in deeper water is declining, especially among the outer reefs. Clearly, the major fish families and species caught by the Sama are found inside *t'bba*.

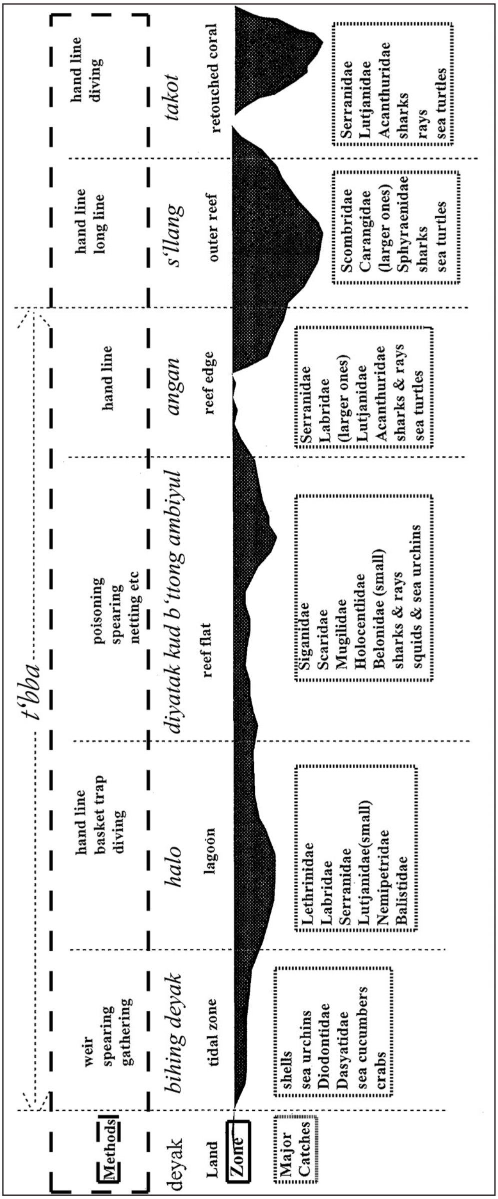

Figure 4. Relationship between marine environments and major fishing methods.

SAMA FISHING AND QUANTITATIVE DATA

During fieldwork, I recorded 101 fishing activities being pursued by the Sama in the Semporna seas. Among these, 43 fishing activities were practiced by the Land Sama, the other 58 by the Sea Sama. Drawing upon these fishing activities I can report on (i) the correlation between each method and catch species or family, and (ii) the average catch rate (kg/hr) of each fishing method.

Fishing methods and targeted fish species

Table 3 shows the total and average catch amount in each fishing method that I recorded (n =101), while Table 4 shows the correlation between the methods employed and the average amount of fish species or family (kg) caught by each fishing method. In this Table, I have added the correlation between other fishing methods, including basket trapping (*bubu*), weir trapping (*bunsud*) and poisoning (*anua*‘), and their major catches based on the ethnographic information collected by interview surveys.

It is obvious that the major fish species caught by the Sama are Siganidae (spinefoots), such as small sized *mugilap* (*Siganus punctatus*) and *belawis* (*Siganus canaliculatus*) or much larger *berang* (*Siganus lineatus*), and Lethrinidae families (emperors), which mainly include young and small sized (>20cm) *anuping* (*Lethrinus nebulosus*), *sakong* (*Lethrinus mahsena*) and *tilus* (*Lethrinus ramak*). Siganids are mainly caught by net fishing and occasionally captured by night spearing as well, while Lethrinids are both caught by net fishing (70%) and by hand line fishing (30%). In fact, Lethrinids are the most common species caught by net fishing.

Other common catches following Siganids and Lethrinids are some species of Carangidae (scads and trevallies), Scaridae (parrotfishes), Nemipteridae (breams), Labridae (wrasses), Serranidae (groupers), Mugilidae (mullets), Mullidae (goatfishes), Pomacentridae (damselfishes) and Hemiramphidae (garfishes). For Carangids, small sized species such as *hande-hande* (*Carangoides bajad*) and much larger species such as *lumasan* (*Caranx*

Table 3. Total and average catch amount in each fishing methods (n=101).

	Netting	Angling	Diving	Spearing	Gathering	Total
Average Amount (kg)	29.3	11.1	3.5	2.3	1.3	
Total Amount (kg)	1845	245	24.8	7	7.9	1915
Sample Number	63	22	7	3	6	101

Table 4. Correlation between the employed methods and catch species.

Rank	Folk Taxon	Scientific Name	English Name	body size*	net	hook	dive	spear	gathering	basket	poison	weir
1	*belawis*	Siganidae	Spinefoots		12.57		1	2				+
	mugilap	*Siganus punctatus*	Spotted spinefoot	10-20cm	++		+					
	belawis	*Siganus canaliculatus*	Black spinefoot	10-20cm	++		+					
	berang	*Siganus lineatus*	Golden lined spinefoot	20-30cm	+		+					
	mugilap	*Siganus guttatus*	Golden spinefoot	20-30cm	+		+					
2	*ketambak*	Lethrinidae	Emperors		5.84	6.5	2.5	2.5		+	+	+
	anuping	*Lethrinus nebulosus*	Spangled emperor	15-40cm	++	++						
	tilus	*Lethrinus ramak*		10-25cm	+	+						
	lafusu	*Lethrinus olivaceus*	Long-nosed emperor	30-50cm	+			+				
	sakong	*Lethrinus mahsena*		15-30cm	+	+						
3	*daing poteh*	Carangidae	Trevallies		1.37	+						+
	hande-hande	*Carangoides bajad*	Blue trevally	10-20cm	++							
		Carangichthys dinema		20-40cm	+							
	lumasan	*Caranx melampyugu*	Bluefin trevally	20-40cm	+							
4	*ogos*	Scaridae	Parrotfishes		1.11	0.18	0.21			+		+
	bataban	*Scarus ghobban*	Blue barred parrotfish	15-35cm	++	+		+				
5	*bukan*	Labridae	Wrasses		0.64	0.86	19			+	+	+
	bukan	*Choerodon anchorago*	Anchor taskfish	15-30cm	++	++	++					
	lampet	*Cheilinus fasciatus*	Scarlet-breasted maori wrasse	15-30cm	+							
6	*kulisi*	Nemipteridae	Breams		0.32	1.59	0.14			+		+
	kulisi	*Nemipterus* spp.	Threadfin bream	15-25cm		++						
	sanengar	*Scolopsis bilineatus*	Monocle bream	15-25cm	+							
7	*selo*	Belonidae	Longtoms	30-50cm	0.57	+		+				
8	*kehapo'*	Serranidae	Groupers		0.04	1.4	1			+	+	+
	bettan	*Epinephelus ongus*	Speckled-fin rockcod	15-25cm		++						
	kukut	*Epinephelus merra*	Honyecomb cod	15-25cm		++						

9	*belanak*	Mugilidae	Mullets	30-40cm	0.31							+
10	*daing keyat*	Lutjanidae	Snappers		0.08	0.5				+	+	
	malumiyat	*Lutjanus kasmira*	Blue-striped seaperch	15-25cm								
11	*timbungan*	Mullidae	Goatfishes		0.22		0.3					
	kamuding	*Parupeneus multifasciatus*	Yellowstripe goatfish	15-25cm								
12	*kagon*		Crabs	10-20cm	2.7			+	+		+	+
13	*tibuk*	Pomacentridae	Damselfishes	10-20cm	0.08		0.14					
14	*tehe tehe*		Sea urchins	5-10cm					1.5			
15	*tombad*	Balistidae	Triggerfishes			0.09				++		
	tombad tinus	*Pseudobalistes flavimarginatus*	Blue finned triggerfish	20-40cm						+		
	kuput	*Balistapus undulates*	Red lined triggerfish	15-25cm		+				+		
16	*pahi/kihampau*	Rajiforms	Rays	20-40cm	0.3	+		++				
17	*leppe‘*	Haemulidae	Sweetlips	30-40cm	+	++	0.14					
18	*keyot*		Crayfishes				++	+				
19	*buntal itigan*	Diodontidae	Porcupinefish	20-40cm	+				0.15			
20	*siput*		Shells						0.15			
21	*kalitan*	Elasmobranchii	Sharks			++		+				
22	*bat*		Sea cucumbers					++	++			
23	*kanuus*		Squids			++	+	+				
24	*kuhita‘*		Octopus				++		+		+	
Remarks					kg	kg	kg	kg	kg			
Sampling Number					70	22	7	4	6			

* = caught specimens only ++ = frequently caught + = caught

melampygus) are usually caught in reef lagoons or reef edges by nets. Large Carangids are also caught by angling, but the Sama fishermen seldom try to catch larger species by angling in the outer reef. For Scarids, small sized *bataban* (*Scarus ghobban*) are mainly caught by net fishing. It is notable that most of Scarids are caught by nets. Mullids such as *kamuding* (*Parupeneus multifasciatus*) are also usually caught by net fishing.

Labrids, Serranids, Lutujanids and Nemipterids are mainly caught by hand line. For Labrids, *bukan* (*Choerodon anchorago*) are most frequently caught. This species grows up to about 50cm in total size, though the average size of the catches is around 30cm, and some of these small sized fish are also caught by nets and spear guns. Nemipterids are also caught by nets in some instances, and common species targeted by the Sama fishing are *kulisi* (*Nemipterus* spp.) and *sanengar* (*Scolopsis bilineatus*). Serranids and Lutujanids are mostly caught by line or angling. Among the Serranids, small sized species such as *kukut* (*Epinephelus merra*) and *bettan* (*Epinephelus ongus*), whose body size is less than 30cm, are mostly caught. Similarly for Lutjanids, such small sized species as *malumiyat* (*Lutjanus kasmira*) are mainly caught. Although it was not observed, interview surveys confirmed that Haemurids are usually caught by line as well.

Based on my interview surveys, basket trapping (*bubu*) can catch some species of Balistids, while these fish are also sometimes caught by angling. In the Semporna seas, the major species caught among Balistids are *tombad tinus* (*Pseudobalistes flavimarginatus*), which grow up to 40cm, and *kuput* (*Balistapus undulates*), which grow up to 30cm in total length. Rays are frequently caught by night spearing, while small sized rays are also caught in nets deployed at night. Diodontids are the only fish caught during gathering activities as they can be easily grabbed because they are unable to swim and float when they are startled and swell up. Sometimes they are netted in shallow reefs.

Besides these fish species, crustaceans (species of crabs and lobsters) and molluscs (octopus and squid) are also captured. Among them, crabs and lobsters are now usually captured in night netting and frequently caught by night or early morning spearing and night diving with a spear gun, while octopus are captured occasionally during foraging and by diving with a spear gun. Squid are caught by night inshore trolling with a special squid lure or by night spearing.

The catch rate of each fishing method

The catch rate is calculated by dividing the total amount of the catch (kg) by the total amount of time (hours) spent and the total number of persons engaged in each fishing method to establish the possible amount of a catch in an hour by a single person using each method. The results indicate that gill-net fishing has the highest catch efficiency rate at 1.84 kg /hr followed by hand line fishing as 1.2 kg/hr (Table 5). The catch rate for spearing and purse seine netting are lower at about 0.8kg/hr. Yet as the sample numbers of these fishing methods were limited, the rate might be higher if the sample size were increased. In any case, it is plausible to conclude that net fishing brings the highest catch rate for modern Sama fishing.

In gathering activities, people commonly collect shellfish and sea urchins, and occasionally crabs (according to the interviews); however these catches also include the inedible shell in the weight gathered. When recounting the catch of these creatures, considering only the edible portions, the catch rate for gathering is dramatically lower at 0.4kg/hr. Similarly the rate of collecting sea cucumber becomes lower at 0.4 kg/hr when re-calculated based on their weight after drying, because over 90 percent of their total weight is composed of water. When we calculate the rate as including their weight of shell and water, the catch rate dramatically increases to 4kg/hr. This data tentatively indicates that gathering can produce a large amount in number and weight of catch in rather a short time, but the real meat catch rate for gathering is in fact much lower than that of other fishing methods.

Table 5. Average catch rate in each fishing method.

Fishing Method	Sample Number	Fishermen (person▪average)	Fishing time (hour▪average)	Catch amount (kg/hour)	Catch rate (kg/hour/person)
Gill Netting	54	1.9	9.7	3.5	1.84
Angling	22	1	7.1	1.2	1.2
Diving	6	1	2.9	1.2	1.2
Purse Seine Netting	2	4	7	3.2	0.82
Crab Netting	7	1	1.5	1.8*	1.8*
Spearing	1	1	2.5	0.8	0.8
Sea Cucumber	2	1	5.5	0.4**	0.4**
Gathering	7	2.3	3	0.4***	0.19
Total	101	-	-	-	-

* shell included
** weight after processing (boiling and drying/ 0.4kg=14.8NISP)
*** shell not included

IMPLICATIONS FOR PREHISTORY

Selection of fishing methods

Butler (1994) examined the relationship between fish feeding behaviour and human predation strategies for a discussion of the variation in Lapita fishing strategies. In her study, she classified the major catch fish family into three groups as herbivores, omnivores and carnivores. Within these three groups, carnivorous and some omnivorous fish, including Serranids, Labrids, Lethrinids, Lutjanids, Haemulids, Balistids, Diodontids, Sphyraenids and Scombrids, usually have large jaws with teeth designed to procure and handle active prey, while herbivorous and some omnivorous fishes, including Scarids, Mugilids, Siganids, Mullids, Achanthurids, Kyphosids, Tetradontids, Diotonditds and Ostraciids, generally have laterally compressed bodies with modified fins and small jaws. The exceptions were some fishes such as Scarids which graze directly on tissues and the by-products of the reef (Butler 1994: 83).

These basic differences in feeding strategies of each fish family and species is obviously important in determining the human capture technique, and I agree with her on this point. For example, when people aim to catch carnivorous fish, line and baited hooks or lures can be the most efficient methods since those fishes seek active prey, while small mouthed herbivores and some omnivores are not going to be attracted to active prey so much and less likely to be lured by a baited hook. To catch these herbivores and omnivores, nets, spears, baskets and poisons are more suitable since these fishes swim relatively slowly in comparison to carnivorous fishes (see Butler 1994: 84, Myers 1989: 247).

Nonetheless, it is hard for the archaeologist to further determine the specific methods by which these herbivorous and omnivorous fish were caught, in what kind of annual, monthly (lunar) and daily (tidal) cycles fishing activities were practiced, based solely on archaeological and general data on fish ecology. This is why we still need the ethno-archaeological approach to collect and examine more detailed fishing data for reconstructing plausible inferences about past fishing activities.

Early studies (Dye 1983, Kirch and Dye 1979, Masse 1989, Rolett 1989) were not generally based on a sufficient volume (e.g., sample number etc.) of quantitative data, though they provide good samples for further comparison with my data as well as other ethnological data collected widely across Oceania (Johannes 1981, Shanker 1997, Wright and Richards 1985).

With regard to the association between netting and major fish captures, Butler (1994: 83) argued that most herbivorous or omnivorous fish can be best caught by nets as they generally have a small jaw and are hard to lure by hooks. Among them the Scarids species are primarily caught by netting in the Sama fishing, while they can be less frequently targeted by spearing (or underwater spearing with spear gun) and angling (see Table 3). Similar tendencies are also observed in Oceania (Dye 1983; Kirch and Dye 1979; Leach and Davidson 1988; Masse 1986, 1989; Wright and Richards 1985). It is plausible to equate a high frequency of use of nets and spears with the high volumes of Scarids bones from archaeological sites.

Besides Scarids, the Sama netted other fish. These included Siganids, Mugilids and Mullids, and small sized Lethrinids, Carangids, Labrids and Belonids (see Table 4). Siganids and Mugilids move between reef flats and outer reefs during their spawning periods. Sama fishing corresponded to behavioural cycles—especially following fish movement after laying eggs. Siganids are also caught by night spearing while Mugilids are mostly caught by nets in Sama fishing, and similar methods for capture of Siganids, Mugilids and Mullids are also recorded in Oceania (Dye 1983, Kirch and Dye 1979, Masse 1989, Wright and Richards 1985). This evidence clearly indicates that these species are primarily netted and occasionally speared, but are not hooked.

Concerning other herbivorous and omnivorous fish mentioned by Butler (1994), the Sama fishing data can only provide ethno-archaeological information for Balistids, which are usually captured by hooks and basket traps, and Diodontids, which are mainly captured by nets or hands (during shellfish gathering). I could not observe and record any capture of Acanthurids, Kyphosids, Tetradontids or Ostraciids during my research and, on the basis of the interview survey of more than ten Sama fishermen, these species are not usually caught.

Among these fish families, Balistids and Acanthurids are more prevalent than others in many prehistoric sites in Oceania. Ethnological or ethno-archaeological records from Oceania attest that they are caught with nets (Dye 1983: 253-54, Johannes 1981: 99, Masse 1986: 90, Wright and Richards 1985: 73), spears (Kirch and Dye 1979: 63) and hooks (Dye 1983: 251, Johannes 1981: 117, Wright and Richards 1985: 73). While this evidence clearly indicates that Balistids and Acanthurids are captured by several methods including angling by contemporary fishers in Oceania and Island Southeast Asia fishers, it might have been much harder in prehistoric times to catch these fish, which have relatively small mouths, by angling because most fish hooks were made from shell, bone and wood, and presumably the size of the hooks would have been larger than that of today. Overall it is obvious that most of the herbivorous and omnivorous fish can be caught by netting but also by other methods—spearing and trapping, as well as poisoning,[5] and thus it is hard to reconstruct the exact method of capture of each family or species simply from the identification of excavated fish bones.

My quantitative data on Sama fishing techniques clearly indicates that carnivorous fish, including Serranids, Lutjanids, Labrids, Lethrinids and Nemipterids, are frequently caught by angling. The high ratio of Serranids captured by angling is notable (see Table 6). Similar findings are also reported for many islands in Oceania (Dye 1983, Kirch and Dye 1979, Masse 1989, Mafutaga a Toeaina o Atafu i Mataula Porirua 2008, Wright and Richards 1985).

Leach and his associates have assessed the relative importance of netting and angling using ratios of Serranids to Scarids in faunal assemblages, based on ethnological records that Serranids are largely caught by hooks, while Scarids are largely caught by nets in shallow water (Leach and Davidson 1988, Leach, Intoh and Smith 1984). Based on his ethno-archaeological data in Palau, Masse (1986) also concludes that Serranids, Lutjanids and Lethrinids are most often caught by angling, while Scarids are mostly caught by nets, while Butler (1994) reaches the same conclusion based on fish feeding strategy. My quantitative fishing data also confirms that these carnivorous fish are mainly caught by angling.

However, as Table 4 shows, there are some cases of carnivorous species being similar to herbivorous and omnivorous species. For instance, small to middle sized carnivorous species of Lethrinids (e.g., *Lethrinus neburosus*) and Lutjanids (e.g., *Lutjanus kasmira*) are sometimes caught by nets, as well as are some species of Labrids (e.g., *Choerodon ancherago*), Nemipterids (e.g., *Scolopis bilineatus*) and Belonids. Masse (1986: 112) noted that behavioural differences between age groups would affect methods of capture as older individuals prefer deeper waters while some Lutjanids and Serranids juveniles are prone to choose estuarine locales.

Although middle to large sized Lethrinids (e.g., *Lethrinus olivaceus*) and Carangids (e.g., large *Caranx* sp. and *Selar* sp.) are generally captured by angling around the outer-reef zones (Johannes 1981, Mafutaga a Toeaina o Atafu i Mataula Porirua 2008), the data on Sama fishing tentatively shows that small sized Carangids (e.g., *Carangoides bajad*) are also captured by nets inside the coral reef. Wright and Richards (1985: 73) also reported that large Caranx sp. (*C. ignobilis*) were only captured by angling while smaller sized Caranx sp. (*C. melampygus*) were mainly caught by both netting and angling.

It should be noted that some smaller-bodied carnivorous fish can also be captured by nets and other methods, such as basket traps and weirs (Masse 1986: 106), while larger carnivorous fish are mainly caught by angling. This ethnological and ethno-archaeological evidence strongly suggests that size estimates of individual specimens particularly for carnivorous species should be incorporated into any model attempting to reconstruct prehistoric fishing practice. The only exception may be Serranids—even smaller-bodied species—which are mostly captured by angling.

Catch rate and labour inputs

Contemporary Sama fishing with modern fishing gear (nylon nets and lines, metal hooks, out or inboard engines) shows that the average catch rate for netting is highest at 1.84kg/people.hr (n=54). The quantitative data collected by Wright and Richards (1985) on Tigak Island led them to estimate an average catch rate for netting as 3.9kg/people.hr (n= 75). Tigak net fishing usually extended over a short time period (less than two hours) and this may account for the much higher catch rate, while Sama fishing trips (particularly Sea Sama ones) usually took a much longer time of over nine hours (averaging 9.7 hours), which included searching, moving and resting time. Consequently, the catch rate becomes lower than that in Tigak.

Yet, the average catch rate for angling by the Sama is 1.2kg/people.hr (n=22), the same as that for angling in Tigak Island (n=574) at 1.2kg/people.hr (Wright and Richards 1985). Most of the angling I recorded was done by the Land Sama in a shorter time (average is 7.1 hour per fishing trip) than the time the Sea Sama took in netting, which may be the reason why the angling catch rate in Sama is similar to that in Tigak.

Although the catch rate of angling is lower than that of netting in both cases, the cost and labour inputs to purchase and maintain fishing gear (nylon lines and various sizes of metal hooks) for angling is obviously lower than these inputs for nets. These considerations may be among the factors that make angling popular for the Sama, particularly the Land Sama who are rarely full-time fishermen. Yet, the situation in the past, when hooks were made of shell, bone or wood and lines of local fibre, would have been very different. The labour inputs in manufacturing and maintaining equipment would be higher than those for modern fishing equipment. The same would apply to manufacturing and the maintaining fibre nets in the past.

Furthermore, the possible catch rate for netting and angling with traditional fishing gear would be different from that for contemporary fishing with modern gear. For angling, to manufacture small hooks was probably difficult and the possible catch rate using thicker fibre lines and larger hooks might be lower than that using thin nylon lines and various sized metal hooks, including those of very small size (see Leach 2006: 117). Unfortunately, the ethno-archaeological studies on contemporary fishing may not provide fishing data comparable with that using traditional or prehistoric gear, since it is near impossible now to observe and record these types of fishing. The only possible approach for valid comparison is experimental archaeology, attempting as Leach (2006) did to replicate each type of fishing with some traditional gear. However, as Leach (2006: 119) noted, his attempt at using a series of replicas of a shell rotating hook failed, producing no capture. Archaeologists are not experimental fishermen trained in the use of such fishing gear (see Leach 2006: 133). Reconstructing the catch rate of prehistoric fishing remains a difficult problem for archaeologists.

Yet, even though the capture rate of modern fishing may not directly indicate that of prehistoric fishing, because the basic nature of each fishing method does not change, the differences in fishing capture rates, both past and present, may be much the same. Based on this understanding, capture rates of Sama and Tigak contemporary inshore fishing indicate that netting may capture more fish than angling. Still, for the Sama the capture rate of netting is not higher than that of angling, while in Tigak the capture rate of netting is three times higher than that of angling, making it difficult to conclude how much higher the catch rate of netting is than that of angling. The rate would be dependent on the marine environment, season and other conditions, and thus more case studies and catch rate data in many locations are needed.

It should be noted that netting basically requires a greater number of people to be effectively conducted, while angling does not. Sama netting is only done by adult men, while not only men but also occasionally children and women engage in angling because at present the necessary gear is readily available. Findings such as these show that people's selection of fishing methods is not simply decided by catch rate but more likely by the purpose of fishing (e.g., expected catch volume, pursued fish species, preferred fishing ground, time of fishing etc.) as well as convenience (e.g., availability of gear and ease of practice).

Beyond netting and angling, the catch rate for Sama night spearing is even lower at 0.8kg/people.hr, possibly because of the very limited sample size (n=1), while the average catch rate for diving with a spear gun is 1.2kg /people.hr (n=6). Wright and Richards (1985) reported for Tigak Island that the average catch rate for day time spearing or diving with a spear gun is 1.2kg/people.hr, while that for night fishing is 3.6kg/people.hr. Although their data for spearing includes diving with a spear gun, requiring the use of modern innovations like snorkels and masks, and thus is not relevant to the reconstruction of prehistoric fishing practices (see Butler 1994: 83), their data and my observations of the Sama fishing, where spearing is mostly practiced during night time, indicates that spearing may be an effective method of night fishing (see also Dye 1983: 255, Johannes 1981: 23-24).

Regarding gathering, my quantitative data tentatively indicates that the catch rate for edible meat by gathering is only 0.4kg/hr, which is much lower than that of any other fishing methods. Although the possible catch rate for past gathering would be different from that of the contemporary gathering, this result should be considered in further discussions of the possible role of gathering among past fishing activities of the region.

Tidal and seasonal factors

Based on the Sama fishing data, inshore fishing is strongly affected by natural rhythms of the lunar, tidal and seasonal cycles (see also Johannes 1981: 32-46). My study was not sufficiently long to provide quantitative data on possible seasonal and annual variations in fishing practice, yet I am convinced that tidal and seasonal factors are important in discussing or reconstructing past inshore fishing in shallow coral seas.

Regarding tidal factors, Sama fishing is more actively pursued during the spring tide, when tide changes most drastically in a month, and during the ebbing or rising tide for daytime net and line fishing. This intensified activity is associated with fish feeding behaviour since many fish increasingly move around to seek food when the tide changes. Similar tendencies were also observed in Oceania, for example, Akimichi (1978: 318) reported that 87.3 percent (n=63) of net fishing by the Lau in the Solomons Islands was carried out during the ebbing tide. In Sama fishing, however, many fishermen start their fishing the ebbing tide and continue fishing until the rising or high tide because during low tide inhibits movement between villages and fishing grounds by boat.

Spearing, poisoning and diving are more frequently practiced at high and low tide as people can see fish more clearly and easily when the water stops moving during these times. Gathering activities are mostly practiced at the low tide by the Sama and others (see Akimichi 1978, Kirch and Dye 1979). The Sama classification and knowledge of tidal changes directly indicate that daily and monthly tidal rhythms are some of the ecological factors that constrain fishing and gathering activities in the short term.

Seasonal or annual cycles are further ecological factors affecting fishing, but in the long term. The seasonal cycle may vary throughout Island Southeast Asia and Oceania. For instance, the Sama people divide their fishing season by two monsoons, and in Oceania seasonal monsoons and cyclones can affect migration of pelagic fish such as flying fish (Chikamori 1988, Firth 1936), sea turtle (Johannes 1981, Ono and Addison 2009), as well as fishing itself.

The seasonal aspects of fishing in a temperate zone, which has more varied and clear seasonal changes, has been widely discussed by archaeologists, while its significance has attracted less attention in previous archaeological discussions about fishing and gathering along tropical coasts. I would argue, however, that the natural cycles—tidal rhythms, lunar and wind cycles—can be major factors in determining fishing and gathering around tropic coasts. For instance, the Sama fishing data and other contemporary fishing data from Oceania show that monthly lunar cycles may affect the type of fish captured, while daily tidal rhythms affect the amount of time each method is practiced. The impacts of natural factors were possibly stronger in prehistoric fishing which saw fishing gear and boats quite different from those used in modern fishing.

Major fish species

Table 6 shows whole fish taxa and their rank in the total catch amount I recorded for contemporary Sama fishing, while Table 7 shows all the fish taxa and their rank in MNI (Minimum Number of Individual) or NISP (Number of Identified Specimens) represented in Neolithic sites that were possibly occupied by the early Austronesian people in Island Southeast Asia and Oceania. One of the big discrepancies between these ethno-archaeological and archaeological data records is the rank of Scarids. It is remarkably high within archaeological records, but not so high in ethnological contexts (see Kirch and

Table 6. Fish taxa (Family) and ranks by total catch amount by the Sama fishing.

Rank	Family	Netting	Angling	Diving	Spearing	Gathering	Total (kg)
1	Siganidae	880			2		882
2	Lethrinidae	409	143		5		552
3	Carangidae	96	++				96
4	Scaridae	78	4	1.5	*		83.5
5	Labridae	45	19	19	*		83
6	Nemipteridae	24	35	1			60
7	Belonidae	40	+		*		40
8	Serranidae	3	31	1			35
9	Mugilidae	22					22
10	Mullidae	16		0.3			16.3
11	Lutjanidae	6	11				17
12	Pomacentridae	6		1			7
13	Balistidae		2				2
14	Haemulidae	+	++	1			1
15	Diodontidae	+				0.9	1
16	Rajiforms	+	+		++		2
Total (kg)		1,845	245	24.8	7	0.9	1915
Sample number		63	22	7	3	6	101 times

* = caught specimens only ++ = frequently caught + = caught

Dye 1979, Masse 1989, Rolett 1989). Although Scarids are always one of the major fish captured by inshore fishing in coral reefs, the evidence suggests that the extraordinarily high rank of Scarids in archaeological contexts might be attributed to characteristics of Scarid bones, i.e., their hardness and subsequent preservation in the record rather than direct result of actual fishing.

Another prominent discrepancy is the high catch numbers of the smaller-bodied species—Siganids, Mugilids, Nemipterids, Belonids, Mullids and Carangids—within the total catch of contemporary Sama fishing. The number and amount (kg) of Siganids is especially high in the contemporary Sama

Table 7. Frequency of major fish families in Bukit Tengkorak and Lapita sites (after Butler 1994, Ono 2003, 2004).

Rank	Family	BT	ECA	EKQ	ECB	EHB	RF-2	TK-4	NT-90	Total
1	Scaridae	441	829	60	28	39	50	288	42	1777
2	Lethrinidae	221	925	58	32	21	53	45	8	1363
3	Serranidae	308	207	25	7	12	20	41	0	620
4	Labridae	197	197	6	8	7	18	25	2	460
5	Balistidae	74	205	17	2	5	8	110	1	422
6	Lutjanidae	208	101	20	7	2	9	10	1	358
7	Diodontidae	91	47	0	29	8	24	61	18	278
8	Elasmobranch	153	34	20	1	1	3	12	2	226
9	Acanthuridae	25	117	30	4	0	2	1	9	188
10	Holocentridae	0	22	21	0	0	2	111	0	156
11	Carangidae	7	67	2	2	0	1	36	0	115
12	Muraenidae	23	28	7	1	1	4	32	0	96
13	Scombridae	1	42	34	2	2	4	3	0	88
14	Belonidae	5	69	0	0	0	1	0	1	76
15	Siganidae	56	0	0	0	0	0	0	0	56
16	Tetradontidae	3	26	0	3	4	0	0	0	36
	Other species	163	276	45	8	4	6	0	0	502
Total		1976	3192	345	134	106	205	775	84	6817
elements recorded		26	33	33	33	33	?	8	?	
mesh size (mm)		3&5	3,5,7	5	5&7	7	5,6,4	6&4	6.2	
Count		MNI	NISP	NISP	NISP	NISP	MNI	NISP	MNI	

fishing (see Table 7). Similar indications that smaller-bodied fish species rank higher are also observed in Oceania, such as the significant catch of Holocentrids in Palau and Marquesas (Masse 1989, Rolett 1989). Also, the highest catch number of inshore fishing in Niuatoputapu was Pomacentrids (Kirch and Dye 1979) and very high catch numbers and amounts of Mugilids caught by netting were witnessed in Tigak (Wrights and Richards 1985).

The majority of smaller-bodied fish recorded for contemporary Sama fishing may be largely the result of a decrease in larger-bodied species in the coastal reefs, which has been caused by the increase of explosive fishing and over-exploitation of inshore species for decades in the research area. Yet the data could indicate that archaeological taphonomic processes (i.e., how plant and animal remains accumulate and are differentially preserved within archaeological sites) are affecting the number of these smaller-bodied fish bones, and the smaller-bodied species—particularly considering that Siganids, Mugilids, Mullids, Bellonids and Carangids could be caught frequently, if netting, trapping and poisoning were used prehistorically.

However, other smaller-bodied species mainly belonging to carnivorous groups, such as Nemipterids and Holocentrids, are more frequently captured by present-day angling with a nylon line and smaller-sized metal hook. As it is hard to estimate or reconstruct how effective traditional angling gear would be in catching such small sized carnivorous fish, it may be risky to rely on contemporary fishing data to identify an earlier method used to capture these smaller-bodied species.[6] However, it should be stressed that these smaller-bodied species were also present in the prehistoric sites as shown in Table 7. In the archaeological sites, the high number of Serranid bones, usually variable in size and including small specimens, indicates that ancient fishing methods could capture these smaller-bodied carnivorous fish, possibly by angling or other methods such as basket trap and weir.

RECONSTRUCTIONS OF EARLY AUSTRONESIAN INSHORE FISHING

In light of the discussions above, in this section I reconstruct the early Austronesian inshore fishing around the Bukit Tengkorak site on the eastern coast of Borneo. As shown in Table 7, the zoo-archaeological analysis of the excavated fish remains from Bukit Tengkorak (Ono 2003, 2004, 2006) has a strong similarity with exploited fish species with early Lapita sites in Oceania.

Bukit Tengkorak was first excavated by the Sabah Museum under direction of Peter Bellwood in 1987 (Bellwood 1989, Bellwood and Koon 1989) and then by a joint team from the University of Science Malaysia and the Sabah Museum in 1994 and 1995 (Chia 1997, 2001, 2003), in 2001 (Ono 2003, 2004, 2006) and from 2002 to 2003 (Chia 2008, 2009) . The total area excavated during these investigations by 2001 was 10.5m^2, and each excavation unearthed a number of fish remains. From these excavations I earlier analysed fish remains excavated during 1994 to 1995 (from the southern part of the site) and in 2001 (from the northern part of the site), identifying a total of 28 fish taxa to family level (NISP=4132, MNI=1976) from 3m^2 selected units (Ono 2006).

Over 99 percent of the identified bones were inshore or coastal coral fish species such as groupers (Serranids), emperors (Lethrinids), parrotfish (Scarids), wrasses (Labrids), snappers (Lutjanids) and triggerfish (Balistids). The number of pelagic fish was very limited: only two bones (vertebrae) were identified as tuna (Scombrids) and one bone as barracuda (Sphyraenids). Since no materials related to fishing (i.e., net sinker, hook, lure) were recovered, these fish remains are the only archaeological data available for analysis and reconstruction of prehistoric fishing.

Based on previous studies in Oceania, I earlier attempted to reconstruct the prehistoric fishing strategies at Bukit Tengkorak by simply following the basic correlation between MNI of each fish family and the estimated major capture method, attributing Scarids, Balistids, Siganids, Mullids and Mugilids to "netting" and Serranids, Lethrinids, Labrids, Lutjanids, Haemulids and Nemipterids to "angling". The result of such a reconstruction clearly showed a high ratio of angling and its importance, as the ratio of the fish correlation to the angling capture among the total MNI was over 51.5 percent, while that of fish correlation to netting was only 32.5 percent (Ono 2004: 102). In addition, I attributed Elasmobranch to spearing (8.1%), Muraenids and Ariids to trapping or poisoning (3.2%), Diodontids and Tetradontids to general foraging (1.5%), and Carangids and Sphyraenids to trolling (0.2%). If such attribution and reconstruction is plausible and acceptable, the archaeological data at Bukit Tengkorak shows that angling was the most popular and important method, and the ratio of angling (51.5%) is higher than that of the Lapita sites Butler (1994) investigated.

However, considering the ethno-archaeological data and discussion presented here, such simple evaluations for the correlation between each fish family and possible capture method is rather inaccurate and some reconsideration is required. Although the middle to larger-size Lethrinids, Labrids and Lutjanids are usually caught by angling, some smaller sized species are captured by netting if the fishing site is inshore sea. Reconsideration of Nemipterids is also called for, since most species are captured by angling, while some species are also captured by netting, so it is much harder to estimate the capture method on a family level.

To integrate these findings into the archaeological reconstruction, the size difference of each identified specimen for these fish family should be taken

Table 8. Bone size classification of the major excavated fish species.

Bone Size	small	middle	large	extra-large	Total MNI
Scaridae	126 (28.7%)	199 (45%)	97 (21.9%)	19 (4.2%)	441
Serranidae	60 (18.8%)	216 (70%)	30 (10%)	2 (0.8%)	308
Lutjanidae	29 (14.1%)	135 (64.9%)	39 (18.6%)	5 (2.2%)	208
Lethrinidae	70 (31.6%)	117 (52.9%)	34 (15.3%)	0	221
Labridae	64 (32.1%)	109 (55.1%)	16 (8%)	8 (4.5%)	197

into account. I earlier attempted to undertake size analysis of all identified bones belonging to the major fish family (Scarids, Serranids, Lutjanids, Lethnids and Labrids) excavated from Bukit Tengkorak (Ono 2006: 101-4). In the present study I sorted the identified bones simply into three to four approximate size categories (small, middle, large, extra-large),[7] since the number of the modern fish references that could be used for the analysis (Leach *et al.* 2001, Reitz and Wing 2008, Seymour 2004) was too limited to estimate their actual body size and weight accurately. Consequently, my size classification here is tentative, though I consider the result may possibly reflect at least the rough size variation of each major family.

Table 8 records the total MNI of each major fish family as sorted by the size variation of identified bones. Table 9 records the result of a new reconstruction of prehistoric capture methods employed around Bukit Tengkorak, based on such zoo-archaeological analysis and the ethno-archaeological or ethnographic data on contemporary fishing by the Sama and in the Pacific.

When based on the ethno-archaeological data of the contemporary inshore fishing, the smaller bodied specimens of Lethrinids, Lutjanids and Labrids, as well as Nemipterids, Sparids and Haemulids, are captured by hook or other methods including nets, hence they are sorted into the category "angling or other methods", while much larger size specimens (middle, large, extra-large) of these families and Serranids would be commonly captured by hooks and thus fall into the "angling" category. With such a classification, the total MNI of fish specimens estimated to be captured by angling is still larger, because there are not so many smaller-bodied specimens of these species recovered from the site (see Table 9).

Regarding other fish species, I sorted Scarids, Siganids, Mullids and Mugilids into the category "netting or other methods", while Balistids and Carangids were placed in the category "angling and netting or other methods" since

Table 9. Reconstructed capture methods at Bukit Tengkorak.

Methods	Family/species	MNI	Total MNI	%
Angling	Serranids	308	771	39%
	Lutjanidae (> middle)	179		
	Labrids (> middle)	133		
	Lethrinids (> middle)	151		
Netting and other methods	Scarids	441	656	33.00%
	Siganids	56		
	Balistids	74		
	Mullids	15		
	Belonids	5		
	Acanthurids	25		
	Kyophosids	1		
	Pomacentridae	28		
	Mugilids	11		
Angling and other methods	Lutjanidae (small)	29	260	13.15%
	Labrids (small)	64		
	Lethrinids (small)	70		
	Nemipterids	9		
	Sparids	28		
	Haemulids	60		
Angling and spearing	Elasmobranch	153	155	7.80%
	Platycephalids	2		
Netting and angling or other methods	Carangids	7	7	0.30%
Various methods	Diodontids	91	122	6.10%
	Tetradontids	3		
	Ariids	5		
	Muraenids	23		
Offshore trolling and angling	Scombrids	1	5	0.20%
	Sphyraenids	4		
Total			1976	

these families are captured both by netting and angling depending upon their size and species on ethnographic and contemporary evidence. Furthermore, it is hard to identify the exact capture method given the current accuracy of archaeological fish bone identification (i.e., family level identification). Other inshore bony fish species, such as Diodontids, Tetradontids, Muraenids and Ariids, are mainly captured by general foraging, trapping and poisoning rather than netting and angling, and are assigned to “various methods” here. Of the offshore pelagic fish species, Elasmobranchs are frequently captured by angling (usually sharks) and spearing (more frequently rays) in contemporary Sama fishing (see Table 1) or fishing in Oceania (Johannes 1981, Ono and Intoh in press, Ono and Addison 2009), and thus they are sorted into “angling or spearing”, while pelagic bony fish species such as Scombrids and Sphyraenids were sorted into “offshore trolling and angling”.

The result differs slight from my previous study, but high frequency of angling (39%) followed by netting (33%) is still apparent, and this is the most prominent character of the reconstructed Bukit Tengkorak fishing. Furthermore, when other categories are included (e.g., angling and other methods, angling and spearing), the frequency of angling increases to over 50 percent of all the methods employed (with the exception of foraging).

Butler’s study (1994: 87-88) reconstructing the Lapita fishing strategies based on fish feeding behaviour and fish capture methods proposed that the major capture methods used by the prehistoric Lapita—those fishing particularly in Mussau and western Melanesia where the early Lapita sites located dated back to 3,300 BP—were almost equally divided into netting/spearing and angling, and sometimes the ratio of angling is slightly higher, while the ratio of netting/spearing to catch herbivorous and omnivorous fish dramatically increased (to over 60-70%) in eastern Melanesia, including Tikopia and Niuatoputapu.

When compared with Butler’s results, the selection and use pattern of fish capture methods at Bukit Tengkorak is similar to that of the early Lapita sites in Mussau and western Melanesia, and confirms the equal importance of angling and netting methods for Austronesian fishing practices in coral reefs and inshore environments. An ideal combination of angling and netting techniques might be one of the most prominent features of the early Austronesian fishing strategies from Island Southeast Asia to Oceania, particularly in western Melanesia.

Furthermore, the ethno-archaeological and ethnographic data on contemporary fishing suggests that early Austronesian-speaking people selected each fishing method according to what fish species they intended to capture, the lunar and seasonal cycles, and the organisation of labour. When considering lunar (or tidal) and seasonal (or annual) cycles more fishing with nets or hooks might be done during the period of ebbing or rising tide, using nets mainly in day time and angling both day and night.

The effect of seasonal or annual cycles on fishing will be different at the location of each archaeological site or island. Around Bukit Tengkorak on the eastern coast of Borneo prehistoric fishing would be more frequently pursued during the months between the two monsoon seasons, such as March to July or November, while night fishing would be more actively pursued during the south-west monsoon season around August to October.

Regarding the organisation of labour as indicated by ethno-archaeological and ethnographical data, netting may be able to catch more fish in number and weight than any other fishing method, but needs to engage more people since netting is a co-operative effort. It may possibly also require a longer labour time to manufacture nets from plant fibres, especially for a larger net, than the production of other fishing tools including hooks and spears. Angling is an individual pursuit with much lighter equipment—such as hooks and lines. Judging the nature of each fishing method, netting with larger net(s) might be practiced occasionally as co-operative fishing by a few or large numbers of people, while angling and netting with a small net (e.g., scoop net) might be practiced more frequently by one person or a few persons.

Beside these two major fishing methods, the variety of fish species excavated from Bukit Tengkorak and the Lapita sites in Oceania indicates that the people employed a variety of capture methods for inshore fishing. Among these practices, spearing was possibly more frequently employed during night time (see also Dye 1983: 255, Johannes 1981: 25-26) with torches of burning coconut husk or other kinds of wood to catch reef fish species (mainly herbivorous and omnivorous species), rays, crabs, lobsters, crustaceans, squids and molluscs. Trapping by basket and possibly by stone or wooden weirs might catch a variety of inshore fish including the smaller-bodied species. The ethno-archaeological data on contemporary fishing by the Sama and in Oceania clearly indicates that many smaller-bodied fish species are also captured by diverse methods and further suggests that smaller-bodied fish might also be frequently captured by these methods in prehistoric fishing, despite their bones rarely surviving for the archaeological record

General foraging entailed gathering shellfish, sea urchin, crabs and octopuses, and occasionally capturing some fish species, such as Diodontids, by hand or spear. Based on ethno-archaeological data, such foraging activities were practiced during the low tide around inter-tidal zones or shallow coral reefs. At Bukit Tengkorak, over 6,000 shellfish and some crab remains were excavated mainly from the southern part of the site, and these shellfish were identified into 15 families (23 species) of gastropods and 7 families (9 species) of bivalves, most of which (20 families) are reef dwelling species (Chia 1997:

191). The major species exploited are Strombidae, Muricidae and Fasciolariidae for gastropods, and Tridacnidae, Arcidae and Lucinidae for bivalves.

With regard to meat value, species middle to large in size belonging to the Muricidae, Faschiolariidae and Tridacnidae families could have played an important role as a source of protein, though shellfish species of these sizes are much harder to collect in recent times around Bukit Tengkorak owing to over-exploitation. My ethno-archaeological data of the contemporary gathering of shellfish, sea urchin and Diodontids on shallow coral reefs shows that the total edible meat weights captured by general foraging is far less than that captured by other fishing methods (see also Kirch and Dye 1979: 68).

Yet the significance of general foraging is its ease of practice. Women and children can engage in it, as ethnographic records suggest. This method in Sama foraging may be characterised as stable because it is affected by the tidal cycle but not by a seasonal cycle (e.g., wind, weather, temperature change), and may be continually practiced throughout the year. Taking into account the nature of general foraging, it can be done by men, women and children and is significant particularly during the monsoon seasons when other fishing activities are inhibited because of strong winds.

Lastly, regarding offshore (outer-reef to pelagic zones) trolling with lure or hook, the fish bones excavated from Bukit Tengkorak clearly show such offshore fishing was rarely or never practiced. There is a specimen of Scombrids and Sphyraenids at the site, but we cannot know whether these specimens were caught by offshore fishing or if they happened to be caught by inshore fishing, since some pelagic species may swim into inner reefs and lagoons and be caught there (see also Masse 1989). In any case, the archaeological data and ethno-archaeological data on contemporary Sama fishing clearly indicate the lesser importance of such offshore fishing around Bukit Tengkorak on the eastern coast of Borneo.

This does not mean that the early Austronesian-speaking population did not have the knowledge and technology for offshore fishing. They did have offshore fishing technology, including the production and use of shell (mainly *Trochus* and *Turbo* sp.) which made lures and large hooks, as some early Lapita sites excavations in Melanesia testify (e.g., Butler 1994; Kirch 1997, 2000) and as linguistic studies indicate (e.g., Osmond 1998, Pawley 2007, Walter 1989). Yet, it should be noted that the number of excavated pelagic fish species, such as Scombrids and Sphyraenids, from these Lapita sites are also small and far fewer than inshore species. The frequency of offshore fishing practices was more likely dependant on the site's location; people might choose to conduct offshore fishing if they inhabit locations with good access to open sea or deep channels as well as reefs and lagoon, as in the case of the EKQ site on Mussau (Butler 1994: 88).

However, the current archaeological evidence relating to the early Austronesian-speaking populations both in Island Southeast Asia and Oceania[8] tentatively indicates that these people preferred to dwell on coasts with developed coral reef(s) or lagoons, and that the intentional selection of such areas might be another component of their fishing strategies, or even be attributed to their overall subsistence strategies.

INTERPRETATIONS

Discussion of results

My reconstruction of early Austronesian fishing strategies, drawing upon my ethno-ecological study of the contemporary Sama fishing and ethno-archaeological data from Oceania, is pertinent to discussions and interpretations of the development of Austronesian fishing both in Island Southeast Asia and Oceania. Like several earlier studies (Butler 1988; Green 1986; Kirch 1988, 1997; Kirch and Dye 1979; Walter 1989), my analysis confirms (i) the predominantly inshore nature of early Austronesian fishing and (ii) the use of a variety of fishing methods. More specific fishing characteristics are (iii) the prevalence of both angling and netting on the eastern coast of Borneo in Island Southeast Asia and as far east as Mussau and Santa Cruz, and of the more exclusive practice of netting (and possibly spearing as well) in Tikopia and Niuatoputapu—all convincingly argued by Butler (1994: 87).

These results suggest that there might have been considerable variation in early Austronesian fishing strategies and inshore fishing practices, particularly for Lapita fishing in Oceania (see also Butler 1994: 87-88). This variation in practices and strategies using different arrays of fishing equipment and techniques might be equally applied to the Island Southeast Asian region. However, a definitive statement cannot be made at this stage because of the very limited number of archaeological sites (particularly ones of comparable age to early Lapita sites) with well preserved fish remains, and because what remains there may be in many places have yet to be investigated archaeologically.

The absence of shell trolling lures and the very few pelagic fish bones in Island Southeast Asia Neolithic sites, including Bukit Tengkorak, imply a major discontinuity between this region and Oceania. It is risky to make any conclusive statement at this stage, given the small number of investigated sites and paucity of data. Nonetheless the present information could suggest that offshore fishing techniques with trolling lures might be an innovation of Lapita fishers somewhere between Borneo and Melanesia, specifically around eastern Wallacea between Maluku and Irian Jaya (Western Papua) where more islands are surrounded by deep sea. Only a few archaeological investigations have been conducted in this region (see Bedford and Sand 2007, Spriggs 2007), so that it largely remains an archaeological *terra incognita* for the time being (see Kirch 1997: 55).

My quantitative data suggests that the catching of some fish families and species correlates with a certain types of capture method, while others can be caught by several methods depending on their body size (see also Reitz and Wing 2008: 73, 266-72), and possibly upon habitation zone as well. Another application of the ethno-archaeological data to archaeological studies is the finding that catches consisted of greater numbers of smaller-bodied species, suggesting that the prehistoric inshore fishers targeted such smaller-bodied species like the contemporary inshore fishing observed. If archaeologists were to adopt finer sieving techniques which would retrieve smaller-bodied species this proposition could be tested (see recommendations below).

My ethno-ecological data establishes the significance of tidal, seasonal (particularly monsoon) and annual cycles as directly affecting or restricting fishing activities. Although my fieldwork was not sufficiently long (over a year) to provide quantitative data on possible seasonal or longer-term variations in fishing practices, the study does demonstrate that these environmental factors do significantly affect fishing activities.

Recommendations

Based upon the findings of my study, I would make four recommendations concerning data collection in future zoo-archaeological and ethno-archaeological studies.

First, regarding the correlation for inshore fishing between fish size and fishing method, I strongly suggest using the size estimate analysis of individually identified fishbone specimens, particularly of major family and species, not only to identify their major capture method in the most accurate way and but also to determine the major fish taxa as a protein source at each site. This would entail development of the analytical capability to identify a greater variety of bone elements including vertebrae, which have the potential to identify smaller-bodied species such as Clupids and Belonids (Toizumi 2007) as well as larger-bodied species such as Scombrids, Carangids, and Sphyraenids (Ono and Addison 2009, Ono and Intoh in press).

Second, regarding an archaeological recovery method designed to judge the volume of small-bodied species more precisely, my study clearly suggests the importance of using finer mesh in excavation. Irrespective of Butler's conclusion (1994: 86) that decisions regarding mesh size, elements recorded and counting units (i.e., both NISP and MNI) do not affect representation of the common fish families in the case of Mussau assemblages, I consider the available data to support her conclusion that mesh size and counting units of the identified fish species in Oceania and Island Southeast Asia are too limited at this stage to apply to all other sites (Butler 1994: 86). I consider that it is still essential to employ fine mesh (>around 3mm at least) screening (see also Reitz, Quitmyer and Marrinan 2009: 17) and water sieving to recover and identify as many faunal remains (particularly small-bodied fish bones) as possible.

Third, regarding the correlation between tidal or seasonal cycles and fishing practice, my data on the contemporary Sama fishing provided useful information for reconstructing the prehistoric fishing at Bukit Tengkorak, but may not equally apply in making ethno-archaeological models of early Austronesian fishing activities and strategies in other sites. To develop a stronger and more flexible ethno-archaeological model, taking into account natural cycles, and to investigate and reconstruct site specific the past fishing activities and strategies, much more quantitative and detailed data recording fish and fishing behaviours, tidal and seasonal changes in each location and coastal environment is needed.

My final recommendation concerns offshore or pelagic fishing. It should be a requirement of future studies to observe and collect quantitative data on offshore fishing in relation to lunar and seasonal cycles, and to record the correlation between each fishing method, captured species and location of fishing grounds. I freely admit that labour and time inputs or catch rates of contemporary offshore fishing with modern fishing gear (e.g., motorboats, nylon lines and factory manufactured lures and hooks) are hard to model or use directly in interpreting archaeological data, just as they are for contemporary inshore fishing. Nonetheless such data should still be significant for comparative studies in order to discuss and identify the nature and role of each fishing method and to reconstruct fishing strategies.

* * *

I accept the opinion or criticism that ethno-archaeological studies and the data on contemporary fishing with modern gear in different economic, subsistence, cultural and social contexts from those of prehistoric fishing is not directly applicable to interpretations or reconstructions of the all aspects of prehistoric fishing. Indeed, I have not introduced and discussed other data,[9] particularly that more directly related to the cash economy and social organisation in the context of contemporary Sama fishing, because this data is hardly relevant to the archaeological discussion and reconstruction of fishing practices.

That said, there is no doubt that various kinds of ethno-archaeological or ethno-ecological data, especially quantitative data of the contemporary Austronesian-speaking population in both inshore and offshore environments, are essential to building our knowledge and understanding of the complex characteristics and contexts of prehistoric Austronesian fishing. I am also convinced, as once advocated by Kirch and Dye (1979: 74), that "ethno-archaeology is not only just an efficient method for archaeologists to approach both the past and traditional or modern fishing activities and strategies, but also it is an integral and indispensable part of the cluster of approaches that together make up our science of the human past"—even today in the early 21st century, 30 years after their ethno-archaeological research on Niuatoputapu in Oceania.

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NOTES

1. Four shell fishhooks were excavated archaeologically in East Timor, but two of them were from an early Holocene site (O'Connor and Veth 2005), while the other two were from the unclear dated layers (Glover 1986). The statement stands that no fishhooks or trolling-lure shanks have been excavated from any Neolithic sites so far in Island Southeast Asia. Likewise, no stone or pottery net sinkers were excavated from the Neolithic sites in Island Southeast, including Bukit Tenkgorak.
2. These fishing methods have been extensively employed since the 1970s, although the number of Sama fishermen using these methods has decreasing in recent times owing to prohibitions by the Malaysian government (Nagatsu 1999, Sather 1997). There has been a dramatic increase of marine police patrols in the Semporna seas after the international kidnapping incidents led by Philippine gangs, such as *Abusayafu* from the late 1990s, and the new government has also put in place a control system that fines fish buyers who sell fish caught by illegal methods, such as dynamite and poison fishing (Ono 2007).
3. Nagatsu (1995: 60) indicates that the replacement by low cost nylon for net and line making material might be another reason that decreased the necessity and significance of women's labour and participation in Sama fishing.
4. Nagatsu (1995: 30) also reported that Sea Sama in Sitangkai Island further identify reef edge with hardly visible bottom as *bowa*' *angan* and reef edge with invisible bottom as *bowa*' *pepak*.

5. Poisoning and trapping can target different fishes, though they are occasionally or complementally employed in recent times (Johannes 1981; Masse 1986, 1989). In Sama fishing, for example, plant poisons are occasionally used with net fishing to increase the catch rate or target schooling fish. Among trapping methods, a variety of baskets and weirs are used corresponding to the habits of targeted fish and tidal changes. Although trapping methods are not so popular in recent Sama fishing, many ethnographic records in Island Southeast Asia and Oceania indicate its important role in traditional fishing (Aldaba 1932, Kubary 1895, Masse 1986, Spoehr 1980).
6. Yet there are some prehistoric sites including Lapita sites which produced some small shell fishhooks, e.g., Lapita sites in Vanuatu (Bedford, pers. comm. 2009) and prehistoric sites in Tokelau (Best 1988, McAlister 2002). A fishhook excavated from Fakaofo atoll in Tokelau is similar to the ethnographic small fish hook used by islanders to catch Holocentridae (McAlister 2002).
7. The measuring part of bone size and its size classification (as small, middle, large etc.) are variable, corresponding to each identified bone element (premaxilla, dentary, maxilla, articulate, quadrate, palatine, phalyngeal clusters and vertebra) and each family (Scarids, Serranids, Lutjanids, Lethrinids and Labrids) in this study. For instances, with vertebra, I measure diameter for its size classifications and I categorised those of Scarids, Labrids, Serranids and Lutjanids as small (Ø<5mm), middle (Ø5mm-<10mm), large (Ø10mm-<15mm) and extra large (Ø≥15mm), while those of Lethrinids were small (Ø<4mm), middle (Ø4mm-<9mm) and large (Ø≥9mm).
8. For instances, most Lapita sites across the Western Pacific (over 40 sites) are located on coastal flat or hill, beach or intertidal zone, back beach and coastal dune (see Bedford and Sand 2007: 8-10).
9. Within the data I obtained during my fieldwork in the eastern coast of Borneo, over 250 fish names in Sama may be useful for further comparative analysis with fish names of other Austronesian languages in searching for possible historical relationship and distribution of similar names for certain fish species among Island Southeast Asia and Oceania. These are potential data for archaeological discussion or reconstruction of prehistoric fishing. Collecting names of marine biotopes may also help to analyse and confirm which families and species are potentially important or abundant in the certain location or society investigated (Ono and Addison 2009.). Regarding the Sama fish names, I will report and discuss them in another paper. Some other data related to the current economic system and organisation among the contemporary Sama society are discussed in Ono 2007.

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ABSTRACT

This article presents quantitative ethno-archaeological data collected from the Austronesian-speaking Sama, eastern coast of Borneo Island, whose fishing is mostly inshore. The aim is to rectify the paucity of ethnological quantitative data on inshore fishing and shellfish gathering, and to provide a basis for a more robust reconstruction of the early Austronesian fishing activities and strategies mainly practiced in inshore environments. Data discussed include seasonal and tidal cycles, captured fish species, the marine environment and catch rates for each fishing method. Comparisons are made with archaeological fish bone data and reconstructed fishing strategies employed by the early Austronesian-speaking populations in Island Southeast Asia and Oceania.

Keywords: ethno-archaeology, early Austronesian fishing strategies, quantitative data, Sama (Borneo)