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Marine resource exploitation on Rapa Island

Archaeology, material culture and ethnography

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Introduction

As Rapa lacked the usual suite of Polynesian domesticated animals, it is not surprising that evidence for marine fishing and marine exploitation in general is strong. However, the discussion of fishing techniques and broader aquatic resource exploitation must be placed within the unique environmental context of the island; no straightforward transference of traditions or interpretations in other parts of Polynesia will suffice to explain the patterns seen here. The cultural adaptations that formed on Rapa are exemplified by a remarkable assemblage of very small fish hooks produced in candlenut endocarp that was recovered from Tangarutu. In the absence of tropical coral reef littoral environments, species of shell so important elsewhere for fish-hook manufacture, such as the pearl oyster *Pinctada margaritifera*, were not locally available on Rapa¹ and creative new solutions had to be found. What follows here, then, is an investigation into Rapan flexibility in modifying cultural techniques and practices to the limitations and idiosyncrasies of the environment in which they lived.

After a description of the remarkably preserved Tangarutu fish hooks, the assemblage will be considered within the context of both Rapan environments and generic Polynesian fishing traditions. The Rapan fish hooks are argued to represent, among other things, the creative confluence of traditional practice and material constraint. Neither cultural mores nor environmental context is seen as a determining factor in its own right. Rather, both are seen to inform each other in generating an inventive solution and, with it, a new trajectory in Polynesian fishing technologies.

The fish-hook assemblage

The fish-hook assemblage from Tangarutu consists of 15 complete hooks and hook fragments. Ten of these have been manufactured from the tough endocarp of the candlenut (*Aleurites moluccana*), with the remaining five produced in bone. Within the candlenut fish-hook assemblage, three specimens are unfinished, thereby allowing additional insights into manufacturing procedures. The candlenut fish hooks also preserve evidence of the *Pandanus* carrier(s) in which they were wrapped, as well as the line fibres lashed below the protruding knobs at the heads of the hooks. The candlenut and bone fish hooks will be discussed in turn.

Candlenut fish hooks

Candlenut seems an unlikely raw material in which to fashion fish hooks, although the use of coconut (*Cocos nucifera*) endocarp is widespread (e.g. see Anell 1955:94–5, 98, 102). The coconut palm grows poorly on Rapa, and perhaps grew not at all in the prehistoric past, while *Aleurites moluccana* is common. The use of candlenut endocarp, however, restricts manufacture to very small fish hooks. The average size of the finished hooks at Tangarutu, measuring from the head to the bend, is 10.04 mm long, with a standard deviation of 0.43 mm. Full measurements are given in Table 9.1. There is a standardised plan to the hook morphology, despite some variation (see Figure 9.1), with all hooks, bar the one broken example, showing an incurving point leg, a thickened bend area, and a protruding knob at the head to keep the line in place. All candlenut hooks can be classified as ‘rotating’; largely by virtue of the abrupt incurve of the terminal end of the point leg – similar to the *fong* hooks of Tobi described by Johannes (1981:117–118). This hook morphology helps to keep the fish on the hook and/or hold the bait on the hook (Johannes 1981:117).

Table 9.1. Maximum dimensions and provenance of all Tangarutu complete and fragmented fish hooks.

Fishhook description		Length (mm)	Width (mm)	Provenance
finished candlenut hook	1	10.04	7.25	E1, Spit 4
	2	10.31	9.20	E1, Spit 4
	3	9.21	6.85 (broken)	E2, Spit 2
	4	9.98	7.55	E1, Spit 4
	5	10.50	7.67	East E1, Spit 4
	6	10.37	7.68	East E1, Spit 4
	7	9.87	7.12	East E1, Spit 14
candlenut hook preform	1	10.08	7.65	E1, Spit 3
	2	13.17	9.09	East E2, Spit 1
	3	6.39 (broken)	8.94	East E1, Spit 1
bone hook*				
shank only	1	29.67	7.28	West R1, Spit 4
shank and bend	2	29.07	3.65	Unstratified
point leg	3	8.78	2.27	East E1, Spit 5
bend	4	22.05	7.07	E2, Spit 2
shank/partial bend	5	33.44	7.70	E1, Spit 4

*None of the bone hooks are complete, so these values represent maximum fragment dimensions. Maximum widths represent maximum fragment widths rather than hook widths.



Figure 9.1. The Tangarutu candlenut finished fish-hook assemblage. Scale in mm. Photograph D. Boyd.

The presence of the three preforms (see Figure 9.2) allows insight into how these hooks were produced. The blank was obtained by cutting a number of straight edges to generate the general outer form of the hook. A hole was then drilled through the blank to initiate the formation of the inner shank, bend and point surfaces (seen most clearly in Figure 9.2c). This hole was then widened through abrasion, and the outer periphery of the fish hook was abraded to the desired finished shape. There are clear parallels here with the production of fish hooks in other materials – most notably shell and bone – and this will be discussed further below. The preforms indicate that the head was one of the last pieces of the hook to be shaped. The general abrasion of finished hook surfaces, as well as the presence of the remnants of line lashing on all but one finished specimen (see Figure 9.3), indicate that the hooks were used. Fragments of a woven *Pandanus* case also adhere to all but one of the finished specimens, and while the hooks could have been wrapped individually, it is conceivable they could have been wrapped together in a woven fish-hook ‘kit’, as seen in Tahiti (see Anell 1955:Plate 3). In this respect, it is notable that the one candlenut fish hook that does not have evidence of lashing or an outer wrapping was recovered from Spit 14 of the Tangarutu excavations, whereas the other finished examples were all recovered in close proximity to one another (refer to Table 9.1).

Bone fish hooks

All the bone fish hooks were manufactured from terrestrial mammal cortical bone, and given the size, density and visibly homogenous texture, as well as the lack of domesticated mammals on Rapa, it is most likely that they were produced from human bone (see Figure 9.4). There are no

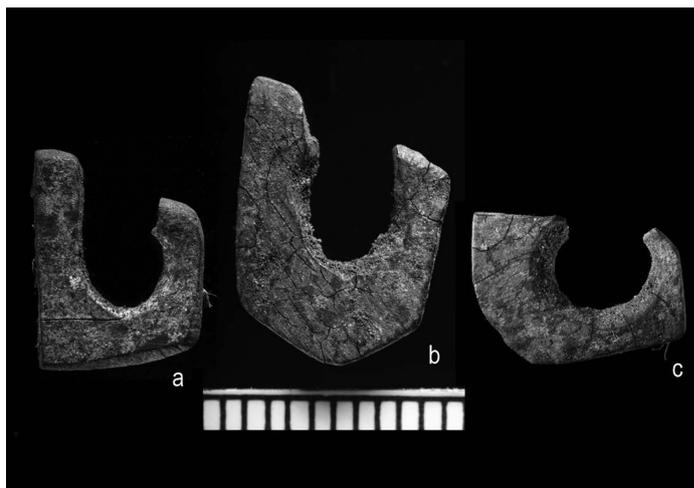


Figure 9.2. The Tangarutu candlenut fish-hook preforms. Scale in mm. Photograph D. Boyd.



Figure 9.3. Finished candlenut fish-hook head and upper shank showing remnants of cordage line attachment lashing; 20x magnification. Photograph P. Piper.

complete examples and thus it cannot be determined whether the bone fish hooks were rotating or jabbing types. Where detectable, features such as an incurving point leg and a projecting-knob form of line attachment match those seen in the candlenut fish hooks. No remnants of either lashing or casing are evident.

Discussion

The stratigraphic placement of the candlenut fish hooks indicates that these were deposited, and probably made, late in the sequence represented at Tangarutu (ca. 1450–1600 AD, based on associated, calibrated radiocarbon dates published in Kennett et al. 2006). This places their manufacture considerably earlier than the first European contact with Rapans in 1792. There is, however, evidence that they continued in production until after European contact.

The unpublished manuscript of Stokes (n.d.), produced in 1920–21, makes mention of small fish hooks produced in candlenut (*tuitui*), although the discussion of them is based on the memory of four older men, none of whom had actually seen such hooks being made. Two forms of candlenut hook were stated as having been manufactured in the past, one from the median section of the endocarp, and one cut ‘from the side of the nut shell’ (Stokes n.d.). The examples recorded from Tangarutu fall into the latter category. Stokes further points out that the hook produced from the side of the endocarp would have been much stronger than the ‘flimsy’ version produced from the cross-section (Stokes n.d.).



Figure 9.4. The Tangarutu bone fish-hook assemblage. Scale in mm. Photograph D. Boyd.

Stokes' discussion of candlenut fish hooks demonstrates that this technological innovation evidenced at Tangarutu was not simply a matter of shortlived experimentation, but a distinctively Rapan solution that continued in use for some centuries. As pointed out by Stokes (n.d.), the use of candlenut endocarp as a raw material for fish-hook manufacture is not recorded elsewhere in Polynesia. However, the evidence contained in the preforms sheds light on how this solution might have come about. The cutting of a blank out of a convex surface, the drilling and subsequent filing of the inner hook form, the abrasion of the outer perimeter and the formation of a knob-shaped head have clear parallels in fish-hook production in bone and shell across Polynesia.

While shell fish-hook blanks were often chipped and filed into shape, rather than sawn (e.g. Kirch and Yen 1982:239; Szabó 2007), bone fish-hook blanks were more commonly generated through sawing (Emory, Bonk and Sinoto 1968:Plate 5). Modification of the inner surfaces of shell fish hooks was initiated through either the drilling of a hole or the creation and enlargement of a notch (Szabó 2007; Kirch and Yen 1982), while the drilling of a central hole in the tab appears to be more standard in bone fish-hook production (e.g. see Emory, Bonk and Sinoto 1968:Plates 4 and 5). Thus, while the use of candlenut endocarp as a raw material can be seen as a technological innovation, the techniques applied are firmly rooted in other Polynesian (and arguably Micronesian) fish-hook manufacturing traditions.

It is also noteworthy that the only other raw material used for the production of the Tangarutu fish hooks is bone. There is no record of any of the standard Polynesian domesticates (pig, dog or chicken) on Rapa, either within the archaeology or ethnographically (Buck 1954:181, 320) and the bone hooks from Tangarutu are probably manufactured from human bone. Where

identifiable, longbone has been used, rather than cranial pieces (see Skinner 1942:217). While the use of human bone for fish-hook production has precedents across Polynesia, its use is commonly bound up in symbolic aspects of war and revenge (e.g. see Best 1929:36), rather than in serving a purely practical need. In the case of Rapa, it is unclear whether the use of human bone for fish hooks had another level of meaning beyond a matter-of-fact answer to a shortage of traditional raw materials. Stokes (n.d.), at least, does not record symbolic meanings beyond practical application. He does, however, posit that materials such as turtle shell and sperm-whale teeth would have been used in the past, despite local assertions to the contrary. The Tangarutu fish-hook assemblage reinforces his Rapan informants' views that candlenut endocarp and human bone were the dominant materials used in the production of hooks (Stokes n.d.).

By virtue of their size and morphology, the candlenut hooks must have been produced to target particular sorts of fish. In particular, these are likely to have been small-mouthed fish capable of being taken effectively with a rotating hook. Stokes (n.d.) cites an informant who stated that both forms of candlenut hook were used for catching '*komokomo*'. The informant had been shown how to use the ring-section hooks to catch *komokomo* as a child, explaining that three such hooks were attached to the line, with the hooks holding fish in place until all three hooks were filled (Stokes n.d.). Stokes further notes that the candlenut hooks described to him corresponded closely, in terms of form, to metal hooks used for catching *komokomo* at the time of his observations (Stokes n.d.). Fishbase (2007) recognises the Rapan *komokomo* as being *Leptoscarus vaigiensis* within the Scaridae. Stokes does not specify which species of fish we should associate with *komokomo* in his unpublished manuscript, and later he (Stokes 1955:334) translates *komokomo* simply as 'a fish'. Randall and Sinoto (1978), however, state that *komokomo* is *L. vaigiensis*, an algal and sea-grass grazer that inhabits sheltered bays, harbours and lagoons. While it seems unlikely that such a fish would take a hook, both the Stokes reference and information provided by a local fisherman to AA in 2002 confirm that the seagrass parrotfish is indeed captured with a small candlenut hook, especially in the month of March. Stokes further records that the *tuitui* fish hooks were also used to catch the damselfish *Stegastes fasciolatus* (Pomacentridae). *S. fasciolatus* is an 'algal farmer' in shallow waters, and as such can be highly territorial of a small patch on the reef (Cardona and Clayton 1999).

In the context of the Rapan assemblages, the appearance of these small fish hooks coincides neatly with the increase in Scaridae and Pomacentridae in the latter half of the upper level of the E1/E2 area. While serranid numbers, which could potentially be associated with angling technologies, do increase in Level III, the increase occurs in the bottom half of the level, with numbers dropping off somewhat in the upper half of the level, and thus does not directly coincide with the appearance of the candlenut fish hooks. The combination of the ethnographic data with those from the fishbone analysis suggests that the occupants of Tangarutu were indeed using candlenut fish hooks to catch *komokomo*/*L. vaigiensis* and *ngangal*/*S. fasciolatus*.

The uniqueness of the Tangarutu candlenut hooks makes direct analogy impossible, but extremely small hooks are reported both archaeologically and ethnographically from other locales in Polynesia and Micronesia. In his observations of fishing practices and archaeological fishing gear from the southern Cook Island of Ma'uke, Walter (1988) reported the use of small shell hooks in association with *titomo* fishing (see also Walter 1991). As described by Walter (1988:222), the hooks were used on a short line for catching a type of mackerel known as *koperu*. Unripe coconut is spread on the water's surface to draw the fish, and after their arrival, the fishermen enter the water and place their baited hooks in the group of feeding fish. Fish are quickly jerked into the boat when caught. While archaeological examples of the hooks used for this specialised form of fishing, identified for the archaeological site of Anai'o on Ma'uke

(Walter 1988), are roughly the same size as those in the Tangarutu assemblage, the *titomo* hooks are jabbing hooks, whereas all those from Tangarutu are rotating.

The ethnographic fishing study undertaken by Johannes (1981) on the Micronesian island of Tobi also discusses the specialised use of small hooks, and in particular, the small *fong*-type rotating fish hook called *haufong*. This is used by Tobians to target triggerfish, which are notorious 'bait-stealers', only nipping at bait unless the hook is small enough for the fish to take it in whole (Johannes 1981:117). Johannes (1981:118) comments that hooks similar to the *haufong* were used in various locales across Oceania, but that in other examples the *fong* (i.e. the recurved point) was longer and thicker, and generally served to hold the bait in place rather than the fish on the hook. While such a generalised distinction is perhaps debatable, what is clear is that the highly standardised though unique Tangarutu fish hooks were produced to a definite format to serve a clear purpose. It should be noted that triggerfish (Balistidae) are altogether absent from the Rapan fishbone assemblages.

Ethnoarchaeology and Rapan marine exploitation

The unpublished manuscript on Rapan lifeways by John F.G. Stokes (n.d.) provides a firsthand account of Rapan fishing, as well as providing some details on the types of littoral invertebrate fauna consumed. There are some clear disparities between Stokes' information and the evidence from the archaeological record, but the ethnographic window provided by his manuscript also provides useful insights into how a living was made in this unique environment. Here, we consider the information provided by Stokes' unpublished manuscript, as well as his published article 'Language in Rapa' (1955), supplemented by Randall and Sinoto (1978) and information on fishing collected by AA during the course of the Rapan excavation season, and assess its potential to inform the archaeological record. Detailed descriptions of fish-capture techniques provide an opportunity to push beyond broad correlations between fish families and capture technologies, and Stokes' notations regarding invertebrate processing methods offer a possible explanation for fragmentation patterns noted archaeologically. Perhaps most significantly, the ethnographic record contains clear statements about cultural ideas surrounding 'edibility' and which marine foods were or were not taken. This information allows us to assess change through time in cultural attitudes towards aquatic food sources, both within the archaeology itself, and with the archaeological and ethnographic records juxtaposed.

Fishing – the ethnographic record

Stokes' (n.d.) manuscript provides ethnographic data on fishing and fishing technology, including hook and line angling, the use of various forms of nets and basket traps, and snares for eeling, as well as Rapan names for the fish commonly caught using each method. The names of fish provided by Stokes (n.d.) and their capture techniques have been matched with the species names given by Randall and Sinoto (1978), and this information is provided in Table 9.2.

Line fishing

The small candlenut hooks used for the capture of *komokomo* and *nganga* have been discussed above, however Stokes (n.d.) also provides information on the use of hook and line for the capture of other fish species. Fishing from canoes with hook and line produced, primarily, the *rari* (a large-mouthed red fish like a rock cod, with large anal spines, possibly the flagtail grouper, *Cephalopholis urodeta* (Lieske and Myers 1994:25). Rensch (1988:237) and Randall and Sinoto (1978:298) also have *rari* as *Epinephelus fasciatus*, the blacktip grouper, which is another red fish of similar form. While relatively small, around 27 cm in average length, it has the reputation

Table 9.2. Aquatic vertebrate and invertebrate fauna covered in Stokes (n.d.) with local names and details of capture techniques where specified.

Family	Species	Rapan name	Capture method (from Stokes n.d.)	Present in assemblage?
Pisces				
Muraenidae (moray eels)			snare	yes
Congridae (conger eels)			snare	yes
Atherinidae (silversides)	<i>Pranesus insularum</i>	kiamu/kiamo	ngake (hand net)	no
Serranidae (groupers/basses)	<i>Cephalopholis urodelus</i>	tumutumuraupoo	hook and line	yes
	<i>Epinephelus fasciatus</i>	rari	hook and line	
Carangidae (jacks)	<i>Pseudocaranx cheilio</i>	matu	rau, hook and line	yes
	<i>Serioloa lalandi</i>	ma'aki	rau, hook and line	
Mullidae (goatfish)	<i>Parupeneus fraterculus</i>	kature/katuri	'inaki ika (basket trap)	yes
Chaetodontidae (butterflyfishes)	<i>Chaetodon</i> spp.	amuamu	'inaki ika	yes
	<i>Chaetodon smithi</i>	vaiti	'inaki ika	
Pomacentridae (damselfishes)	<i>Stegastes fasciolatus</i>	nganga	candlenut hook	yes
Labridae (wrasses)	<i>Gomphosus varius</i>	pokou	'inaki ika	yes
	<i>Hologymnosus</i> sp.	pokou	'inaki ika	
	<i>Pseudolabrus inscriptus</i>	kariva	'inaki ika	
	<i>Thalassoma lutescens</i>	pokou	'inaki ika	
Scaridae (parrotfishes)	<i>Leptoscarus vaigiensis</i>	komokomo	spearing	yes
	<i>Scarus chlorodon</i>	pahoro	candlenut hook, toto (oval dip net)	
	<i>Scarus ghobban</i>	para	dip net	
	<i>Scarus globiceps</i>	pahoro	'inaki ika	
			'inaki ika	
			'inaki ika	
Acanthuridae (surgeonfishes)	<i>Acanthurus leucopareius</i>	mama/ma'a ma'a	toto	yes
Echinoidea				
Echinidae	'Echinus sp.'	vana		No
Crustacea¹				
Palinuridae (marine crayfish)	probably <i>Panulirus ascuensis</i>	koura	'inaki ika (basket trap)	not noted
Atyidae (river shrimps)	probably <i>Caridina rapaensis</i>	koura kotae		not noted
Bathysquillidae	<i>Bathysquilla microps</i> (Stokes: <i>Squilla</i> sp.)	pongaponga		not noted
Grapsidae	probably <i>Leptograpsis variegatus</i> (Stokes: 'rock crab found at base of cliffs')	karami		yes
Carpiliidae	? <i>Carpilius convexus</i> (Stokes: 'rock crab – common form')	papaa		yes
Ocypodidae	<i>Uca tetragonon</i> (Stokes: 'small mud crab with large red claw')	tararoa		possibly
Portunidae (swimming crabs)	<i>Thalamita cerasma</i> (Stokes: 'swimming crab')	tumomi		possibly
?	species unknown (Stokes: 'small crab found under stones')	kōrao		?
?	species unknown – recently moulted crab? (Stokes: 'small rock crab with a soft shell')	pakapakaraumia		?
Mollusca				
Nacellidae	'a limpet' – probably <i>Cellana tahitensis</i>	pangi		yes
Trochidae	<i>Trochus radiatus</i> (observed by Stokes in midden deposits)	name unknown		yes
Neritidae	<i>Nerita morio</i>	'i'i		yes
Cerithiidae	<i>Clypeomorus batillariaeformis</i> (observed by Stokes in midden deposits)	name unknown		yes
Ranellidae?	'Triton sp.'	pu		no
Arcidae	<i>Anadara</i> (= <i>Arca</i>) sp.	akaikai		no
Mytilidae	<i>Modiolus</i> sp.	piuu		yes
Isognomonidae	<i>Melina</i> sp.	kotakota		no
Chamidae	<i>Chama</i> sp.	pa'ua		yes
Spondylidae	<i>Spondylus</i> sp.	pa'ua		no
Psammobiidae	<i>Asaphis violascens</i>	ka'i		no
Tellinidae	<i>Tellina rugosa</i>	pipi		yes
	<i>Tellina</i> sp. ('small')			
	<i>Tellina scobinata</i>	tupere		yes
Veneridae	<i>Gafrarium pectinatum</i>	mitata		yes
	<i>Periglypta reticulata</i>	tupere		yes
	'Venus sp.'	tupere		?

in Tahiti of never being poisonous (Bagnis et al. 1974:106), unlike many snappers and coral trout. Two carangids (*matu*, *maaki*) were also caught by hook and line. Randall and Sinoto (1978:299) equate these with *Pseudocaranx cheilio* and *Seriola lalandi* respectively. The tough wood of the *mairari* shrub (*Dodonea viscosa*) was used to make large and medium-sized bait hooks by training the branches to grow in the required shape. A hook of *mairari* wood with a *tuitui* point was used to catch albacore (*ahi*). Temporary hooks were tipped with *rari* anal spines (Stokes n.d.:259–262). Pearl shell was absent at Rapa, but turtle shell and whale bone may have been used in earlier days.

Rau (leaf sweeps)

Stokes (n.d.) describes the occasional use of large leaf sweeps (*rau*) for fishing. These consisted of two wings (*rau*) of stiff rope with suspended *ti* leaves attached to a central *pohue*, or pound, and they were used to drive fish, as in using a seine net. Stokes (n.d.) observed one catch, which included *matu* (*Pseudocaranx cheilio*) and *maaki* (*Serioloa lalandi*) and a large quantity of unnamed smaller fish. Although deployed infrequently in modern times, the leaf sweep is said to have been an ancient form of fishing on Rapa.

Netting

Stokes (n.d.) states that net fishing had been largely abandoned at the time of his visit, however ‘... in former days [it] was of the greatest importance’. Nets (*kupenga*) used included seines, hand nets and dip nets. Seine nets were used either in shallow water or from canoes further out, but no details of fish catches are provided. Seines were also used for the capture of turtles. Hand nets (*ngake*) attached to two sticks were used to capture a small fish called *kiamo*, which Randall and Sinoto (1978) identify as the silverside *Pranesus insularum*. Dip nets (*toto*) were said to have been used for the capture of *mama* (*Acanthurus leucopareius*) and *komokomo* (*Leptoscarus vagiensis*). These were oval in shape with a single handle and could be operated either by a single person or with others driving the fish.

Basket traps

Basket traps (*inaki ika*), generally made from *kiekie*, were also used for fishing and crayfishing. These traps are used in the month of November to capture *kature*, which Randall and Sinoto (1978) name as the goatfish *Parupeneus fraterculus*. In addition to the seasonal capture of *kature*, *inaki ika* are also used to take *pahoro* (*Scarus chlorodon*, *Scarus globiceps*), *para* (*Scarus ghobban*), *keikei* (taxon unknown), *amuamu* (*Chaetodon* spp.), *vaiti* (*Chaetodon smithi*), *poko* (*Gomphosus varius*, *Hologymnous* sp., *Thalassoma lutescens*) and *kariva* (*Pseudolabrus inscriptus*) (Randall and Sinoto 1978; Stokes n.d.).

Eel snaring

Marine eels were snared in the reef shallows by women (Stokes n.d.). The eel snare (*ngati*) consisted of two sticks, one of which held a bait, and the other a slip noose. Following snaring, the eel was dashed against the rocks to kill it.

Spearing

Fish were caught in shallow water by casting or stabbing a wooden spear. This was generally done from shore or when wading, and spears were also carried in canoes. Fish caught by this method were parrotfish and ‘other shore feeders’, with crayfish also taken using spears from canoes (Stokes n.d.).

Stone weirs

Stone fish traps (*pa ika*), regarded as of ancient origin, can be seen along the margins of east coast bays, although by the 1920s it seems they were no longer used. Stokes (n.d.) notes the use

of one form that consisted of stone-built leaders and a *ngake* for the capture of *kiamo* (*Pranesus insularum*), and also that spearing was used for taking fish from weirs.

Other ethnographic data on fishing

Enquiries of an experienced fisherman on Rapa in 2002 (Mr Teraura Oitokaia, interviewed by his daughter, Roti Oitokaia) elicited the information that *rari* was still a popular fish, especially when it was fattest, from March to May. *Komokomo* (above), apparently known also as *tapio*, is taken by hook in March and by diving from December to January. *Nanue* and similar fish called *pakavai* and *karamami* are caught from April to September. According to Bagnis et al. (1974), *nanue* is herbivorous, a seaweed feeder, and a popular subtropical food fish. Randall and Sinoto (1978) equate all three names with varying sizes of the rudderfish *Kyphosus bigibbus*. It is caught by driving schools towards the shore, using seines of coconut fronds. If there were fish remains from middens along the harbourside, these might well contain *nanue*. Other species caught today include flying fish or *marara* (*Cypselurus* sp.), which are in best condition in April, and the *parapo'atu*, which arrives at Rapa in March to eat the *maamanga* (identified by Stokes (n.d.) as a type of seaweed). Randall and Sinoto (1978) identify *parapo'atu* as the rabbitfish *Siganus argenteus*. Perhaps the most interesting aspect of this evidence is the well-defined seasonality of Rapan fishing.

Gathering of aquatic invertebrates – the ethnographic record

Stokes (n.d. 1955) provides much less information about invertebrate collection and consumption than he does about fish and fishing. Exploited crustaceans are listed and given their Rapan names, and although virtually no information on capture is provided, Stokes does state whether aquatic invertebrates were normally consumed cooked or raw. Similar information is provided for urchins. For molluscs, Stokes (n.d.) generally provides both local and scientific names for taxa gathered and consumed, as well as information about whether the animals were eaten cooked or raw, with occasional information about processing techniques. Of particular interest with regard to molluscs, Stokes (n.d.) casually investigated eroding shell-midden deposits in various locations around Rapa. He recorded the major taxa present and reports this information, together with the then-current 'edibility' status of these species as provided by contemporary informants. Both the archaeological and ethnographic elements of this survey provide revealing points of comparison with the Tangarutu record.

Stokes (n.d.) lists a variety of medium-large crustaceans consumed as food on Rapa at the time of his fieldwork. The marine crayfish, or *koura* (probably the locally common *Panulirus pascuensis*), is at the top of the list, and also listed as prominent among exchange items with early European voyagers in Rapan waters (Barratt 1988:201). In a section of the Stokes manuscript detailing fishing technologies, he mentions that crayfish were taken in basket traps (Stokes n.d.). Stokes (n.d.) also names the river shrimp, *koura kotae* (probably *Caridina rapaensis* in the Atyidae family), and a species of stomatopod termed *pongaponga* (probably *Bathysquilla microps*) among species of exploited Crustacea. All were apparently consumed cooked. None of these species were obviously recognisable within the archaeological samples from Tangarutu,² but a lack of reference specimens means that less-diagnostic fragments might have been overlooked. Even so, the majority of the Tangarutu crustacean remains clearly derives from species of brachyuran crab.

Stokes (n.d.) lists seven types of crab, named only by local names, accompanied by descriptions of varying usefulness. The *tararoa*, described as 'a small mud crab with a red claw', is clearly *Uca tetragonan*, although an identification for the *kōlao* – 'a small crab found under stones' – is more elusive. All named taxa bar the unidentified *kōlao* and *pakapakaraumia* (a crab

with a 'soft shell', perhaps a general term for newly moulted crabs) can be assigned to a species with relative confidence with the aid of distributional checklists and databases cataloguing French Polynesian crustaceans (Poupin 1996, 1998; also <http://decapoda.free.fr/>).

Of the crab taxa listed by Stokes (n.d.), *karami* (*Leptograpsis variegatus*) and *papaa* (*Carpilius convexus*) are certainly represented in the Tangarutu assemblage, with possible additional occurrences of *tararoa* (*Uca tetragonan*) and *tumomi* (*Thalamita cerasma*). Levels of fragmentation within the assemblage are such that reference specimens would be required for full identification and quantification. Nevertheless, with these provisional identifications in hand, it is clear that relatively large and sometimes aggressive and very mobile crabs were being taken as food both archaeologically and ethnographically.

Although Stokes (n.d.) gives no information on crab capture, it is possible that some crabs were caught in basket traps that were laid for the capture of various fish and possibly also crayfish (see above). Some information on crab capture on Rapa was provided to AA by Teraura Oitokaia. Apparently, crabs are caught all year round and are captured by pressing down on the carapace, flipping them over, and piercing the eyes with the thumb. Sticks are used to catch those secreted in holes. The species, or perhaps group of species, captured in these ways is not specified.

Urchins are mentioned only briefly by Stokes (n.d.), who provides the local name *vana* for a species of *Echinus*. It is likely that the attribution to *Echinus* is incorrect and was simply a shorthand reference to 'urchins' using a well-known European/Atlantic genus, in much the same way as '*Chiton* sp.' is sometimes used to refer to polyplacophorans generally rather than those in the genus *Chiton* or family Chitonidae per se. There is no description given to guide scientific identification, but clearly from Stokes' (n.d.) record, urchins were collected, and he states they were eaten raw. The collection of urchins for food was also mentioned by Teraura Oitokaia in information passed on to AA. The species being discussed is unclear, but Mr Oitokaia indicated a preference for collection before spawning.

Certainly if the urchin in question was *Diadema setosum*, hand collection is unlikely, given the length and toxicity of the spines. This implies that some sort of tool-assisted capture method was in use, and as with crabs it is possible that urchins were caught on occasion in basket traps. As detailed in Chapter 8, the relatively low levels of spine and test fragments present in the Tangarutu deposits relative to the number of mouth parts suggest that preliminary urchin processing took place away from Tangarutu shelter.

With regard to molluscs, information about cephalopods, gastropods and bivalves is provided by Stokes (n.d.). Three species of cephalopod (two octopuses and a squid) are mentioned as being taken and eaten either cooked or raw, with the archaeology having, necessarily, nothing to add to this information. Stokes (n.d.) goes on to list bivalves and gastropods eaten or known to be edible to contemporary informants, and those he observed in eroding midden deposits. Although he states that shelled molluscs were not widely collected or eaten on Rapa during his stay, save by children, a fairly wide range of molluscs is listed, along with local names and occasional additional information.

Stokes' (n.d.) list of mollusc species named as food sources by local informants leans heavily towards bivalves, with only a few gastropods named. Hard-shore taxa include *Chama* sp., *Spondylus* sp., *Modiolus* sp. mussels and *Isognomon* (= *Melina*) sp., while soft-shore species include *Gafrarium pectinatum*, various species within the Tellinidae, *Asaphis violascens*, *Anadara* (= *Arca*) sp. and *Periglypta reticulata*. Stokes (n.d.) observed the colonial soft-shore bivalve *Gafrarium pectinatum* to be the most commonly consumed mollusc, eaten either raw or cooked. Only three gastropods are included in Stokes' (n.d.) list, including a limpet identified as *Patella*

(but more likely *Cellana*, which was until recently placed in the Patellidae), the endemic *Nerita morio*, and a 'triton' species. A subset of those molluscs listed by Stokes (n.d.) was named by Mr Oitokaia. He mentions only one gastropod, the *pangi'i* limpet. Mussels, *Isognomon* sp. and *Gafrarium pectinatum* are the most regularly taken of the bivalves, with *Tellina rugosa* and *T. scobinata* now stated as rare on the island.

In Stokes' wanderings around the island, he came across shells deposited on ridgelines, which he took – doubtless correctly – to represent midden refuse. He notes the presence in a number of locations of *Chama* sp. and *Spondylus* sp., with the former being common enough for Stokes to consider it one of the major molluscan foods of past times. Also noted as being present on the hillslopes were pieces of the unidentified *pu* whelk and *Trochus* sp. Of the latter, Stokes (n.d.) states that there was no local name at the time of his investigations. It is likely, based on the Tangarutu results, that this was *Trochus radiatus*. Of particular interest is Stokes' discussion of the diminutive horn snail *Clypeomorus batillariaeformis*. In a casual investigation of the remnants of a hearth within a 'cliff shelter', he notes the presence of crabs' claws and a number of shells, including 165 *Gafrarium pectinatum* valves and 550 *Clypeomorus batillariaeformis* – nearly all of which were broken. Although Stokes' informants knew of no local name for *C. batillariaeformis* and did not consider it a food source, Stokes says it was the most common shell in the 'backwaters of the harbour' and surmised that it was probably an 'article of diet' in the past. This conclusion is confirmed by the presence of *C. batillariaeformis* in the Tangarutu midden.

Ethnographic information and the archaeological record

The early 20th century observations of Stokes, together with information provided to Anderson by Mr Oitokaia, allow us to pinpoint changing subsistence practices through time relating to both environmental changes and shifts in cultural frameworks.

The information on fishing techniques and the taxa exploited provided by Stokes (n.d.) generally provides a good fit with the archaeological fishbone assemblages from Rapa. Although identification of the archaeological material was only undertaken to family level, many of the species discussed by Stokes are represented, generally strongly, within families present in the assemblages.

Both the archaeological analysis and ethnographic data suggest that netting and the use of basket traps are likely to have been important throughout the sequence at Tangarutu, with angling likely increasing in importance in the latter stage of occupation. Stokes (n.d.) lists species in the Scaridae, Chaetodontidae and Labridae as being caught using basket traps (Table 9.2), and these taxa featuring prominently throughout the Tangarutu sequence. Eels can be caught using a number of techniques, including netting, but the fact that they are nocturnal while the other taxa present are diurnal suggests that perhaps another method was employed, unless nets were left set overnight. Several authors report the use of basket traps to capture eels ethnographically throughout the Pacific (Masse 1986; Goto 1990; Davidson et al. 2002), although Stokes (n.d.) does not list eels among the taxa captured using this method. The fact that eel snaring is documented for Rapa (Stokes n.d.) means that this also must be considered a possible method of capture at Tangarutu. The data from Tangarutu suggests an increase in angling late in the sequence, as evidenced by the concurrent increase in Scaridae and Pomacentridae stated by Stokes to be taken with *tuitui* hooks, and the appearance of candlenut fish hooks as discussed above. Species in the Serranidae and Lethrinidae, most commonly caught with a hook and line, also increase in the upper portion of the site.

While the Stokes data and the information obtained in 2002 provide a good fit with the high-ranking taxa from Tangarutu, there are several taxa mentioned in these accounts that are

either absent or rank very low in the assemblages. The first of these are the small silversides, *kiamol/Pranesus insularum*. These are either wholly absent, or accounted for by some of the bones that were not in the reference collection. Silversides are very small, slender fish, growing to an average length of around 10 cm (Randall 2005), so their absence may be due to taphonomic factors. The goatfish, *kature/Parupeneus fraterculus*, while present, is scarce at Tangarutu. Mullids have very fragile bones (Bilton 2001), so there may again be a taphonomic explanation for this. However, Stokes (n.d.) notes that these fish are caught seasonally in November, so it is also possible that their absence reflects seasonality or sampling issues. Other fish mentioned in the ethnographic records that do not feature prominently, but are present in the Rapa assemblages, are the carangids *matul/Pseudocaranx cheilio* and *maakil/Serioloa lalandi*, the acanthurid *mamal/Acanthurus leucopareius*, the kyphosids *Nanue, pakavai* and *karamami (K. bigibbus)*, the exocoetid *mararal/Cypselurus* sp., and the siganid *parapo'atu/Siganus argenteus*. Taphonomic factors may account for the low numbers of exocoetids and siganids, and the seasonal nature of fishing on Rapa may also provide an explanation for the low occurrence of many of these taxa in the archaeological record. There are also several low-ranking taxa in the assemblages that are not mentioned in the ethnographic information (see Table 9.3).

Stokes spends considerably less time discussing marine invertebrates, but comparison of his information with the midden record from Tangarutu is revealing nevertheless. The species of molluscs listed by Stokes (n.d.) are virtually all present in the Tangarutu midden sample, outwardly signalling some sort of constancy through time. However, the relative importance of various taxa seems to alter dramatically. At the most general level, there seems to be a clear swing away from gastropods as the most frequently collected and consumed class of mollusc to a reliance on bivalves by the time of Stokes' observations. While most of the bivalve species that Stokes lists *are* present in the Tangarutu sample, numbers are very low, with only occasional, and sometimes solitary, specimens. Viewed another way, this shift from gastropods to bivalves can equally be seen as a shift from hard-shore to soft-shore species. This may reflect changing coastal conditions, with increased progradation in modern times, but more data would be required to fully assess that possibility.

That things may have been more complex than a straightforward transition from rockier to more sediment-rich littoral zones is suggested by the pattern seen in *Chama* and *Spondylus*. Both of these genera cement the lower valve to a hard substrate, and as such are associated with

Table 9.3. Fish taxa not mentioned by Stokes (n.d.).

Family	Common/Rapan name if known
Belontiidae	needlefishes
Exocoetidae	flyingfishes
Holocentridae	squirrelfishes
Aulostomidae	trumpetfishes
Lethrinidae	emperorfishes
Kyphosidae	rudderfishes
Mugilidae	mulletts
Siganidae (<i>Siganus argenteus</i>)	rabbitfishes (parapuata – small/moroa – large)
Bothidae	lefteye flounders
Monacanthidae	filefishes
Diodontidae	porcupinefishes

hard shores. However, the numbers of *Chama* are low in the Tangarutu sample – despite a preponderance of hard-shore taxa – and according to Stokes were important at the time of his data collection. *Chama pacifica* is represented by only 12 fragments in E1 and a single fragment in E2. Of these 13 fragments, three are heavily worn and cannot have entered the site with a live mollusc inside. There are no *Spondylus* sp. remains in the Tangarutu sample at all.

At present, the same comparisons between Stokes' information and the results of midden analysis cannot be extended to the crustaceans or echinoderms. Species-level data would be required on both sides. It is apparent that brachyuran crabs and urchins have been a fairly stable part of the diet through time on Rapa, although the midden data at least would suggest that their importance has fluctuated.

Dynamic environments and culture through time

Drawing together the archaeological and ethnographic data on marine exploitation on Rapa, there is clear evidence of change through time, as on other East Polynesian islands, such as Aitutaki (Allen 2002). Some of these changes are quite specific, such as those seen in fishing technologies, whereas others concern the broad nature of marine resource use. Environmental change is surely playing a part, and a palaeoecological investigation of the marine-derived faunas through time demonstrates the subtlety of the dynamics of Anarua Bay. Following a discussion of clear trajectories of change in the exploitation of marine resources, we assess, as a whole, the various lines of evidence from both fish and invertebrate fauna to look at shifts in the nature of Anarua Bay and human interaction with it through time.

Elements of change

The rising importance of angling

The archaeological data from Tangarutu point to a fishing strategy focused mainly on the use of nets and basket traps, however the ethnographic data provided by Stokes (n.d.) indicates that the use of hook and line had overtaken these methods in more modern times. While Stokes' information does provide details of netting and basket trapping, he points out that these methods have either fallen into disuse, or are seldom practised. Indeed, he speaks of their occasional use as a 'fad'. The ethnographic data collected by Anderson in 2002 also emphasises hook and line fishing. This would appear to be a continuation of the changes that can be seen in the latter stage of occupation at Tangarutu, where a rise in angling is clearly evident and fish hooks appear in the archaeological record.

The rise in importance of soft-shore niches

As detailed above, the rocky/hard-shore-dominated molluscan assemblage from Tangarutu contrasts with the information on molluscan foods supplied by Stokes (n.d.). Stokes (n.d.) does mention hard-shore species, and soft-shore bivalves are present in the Tangarutu assemblage, so nothing as dramatic as a faunal turnover is evidenced. Even so, the transition from a hard-shore gastropod-dominated focus to a soft-shore bivalve one speaks to a change in the nature of littoral habitats and with it, approaches to the gathering of shellfish. Such shifts in species availability are apparently not uncommon in the context of Anarua Bay, and will be discussed further below.

Shifts in the composition of fish catches

While there is a considerable amount of stability in the taxa commonly exploited at Tangarutu, the changes in relative abundance of these taxa throughout the archaeological sequence are quite pronounced. The implications of these changes in terms of ecology and fishing strategies will be considered below. The archaeological data show a reliance on Scaridae at initial occupation,

lasting throughout Level I and extending into the base of Level II, although giving way somewhat to Muraenidae at this stage. Above Spit 13, in the mid section of Level II, there is a dramatic increase in the occurrence of Chaetodontidae, rising from 7% of the assemblage at the base of that level to 23%, with Scaridae numbers dropping to only 6% of the assemblage. Muraenidae ranks second in terms of relative abundance throughout Level II. The uppermost level of the site sees further change, with Chaetodontidae numbers decreasing and an increase in Serranidae in the bottom half of the level. This changes again in the top half of the level, with Scaridae returning to the position of top-ranking taxon.

Shifts in the composition of molluscan assemblages beyond hard/soft shore

While the hard-shore/soft-shore dichotomy between the archaeological and ethnographic records is distinctive, a number of more subtle changes can be detected within hard-shore assemblages of the Tangarutu sample. Figure 9.5 shows the relative proportions of the four major mollusc species, spit by spit, for squares E1 and E2. There are clear spatial differences in deposition between E1 and E2, despite broadly similar changes. However, the strong stratigraphic patterning in the deposits also validates interpretations of change through time.

Although sample sizes differ widely between spits, this percentage-based view of composition still highlights some noteworthy patterns. *Nerita morio* is clearly dominant in the uppermost spits, with *Gafrarium pectinatum* and then *Clypeomorus batillariaeformis* taking over in relative importance from spits 3–6 in E1, and 3–7 in E2. The limpet *Cellana tabitensis* makes the strongest contribution from spits 7 to 13 in E1, and in Spit 14 in E2. Below this, *Nerita morio* is again the most important species in E1, with *Clypeomorus batillariaeformis* dominating the much smaller samples towards the base of E2.

These differences in relative abundance of molluscan taxa in the Tangarutu midden hint at environmental transformations considerably more subtle than swings between hard-shore and soft-shore environments. *Nerita morio*, *Cellana tabitensis* and *Clypeomorus batillariaeformis* are all microphagous algal grazers on hard surfaces. Indeed, *Gafrarium pectinatum* is the only major mollusc species represented in the Tangarutu assemblage that is not an algal grazer. This hints that the changes in community structure and composition may be related to shifts in the nature and coverage of algae in Anarua Bay. Overlying the urchin and fish data adds increasing weight to this argument.

Algae: The impact of putative changes in the lowest trophic level at Anarua Bay

The shell data from Tangarutu clearly show shifts in the local abundance and availability of algal-grazing taxa through time. However, algae feeders also characterise the urchin sample and a notable proportion of the fish assemblage from Tangarutu. As with the Tangarutu shell, changes in the availability and exploitation of various taxa through time are conspicuous (see Figure 9.6).

The urchin *Diadema setosum* grazes on non-crustose filamentous algal turfs within and below the intertidal zone. Studies have shown that *Diadema* spp. is one of the major grazers and bioeroders in inshore contexts, with herbivorous fish, such as those in the Scaridae, Acanthuridae and Pomacentridae, playing a relatively minor role in overall algae removal in habitats conducive to urchins (Foster 1987). Indeed, following a mass die-off of the Caribbean *Diadema antillarum*, algal cover in Jamaican inshore habitats increased markedly to a mean of 95% coverage of recorded substrates (Hughes et al. 1987; see also Liddell and Ohlhorst 1986). *Diadema* density in inshore habitats appears to be influenced by a number of features. In terms of the physical nature of preferred habitats, *Diadema* prefers coarser sediments, shunning muddy or silty substrates, dislikes complex reef architecture, and avoids high-wave-energy areas (Foster 1987; Dumas et al. 2007). *Diadema* further prefers micro- over macroalgae, avoiding *Sargassum*

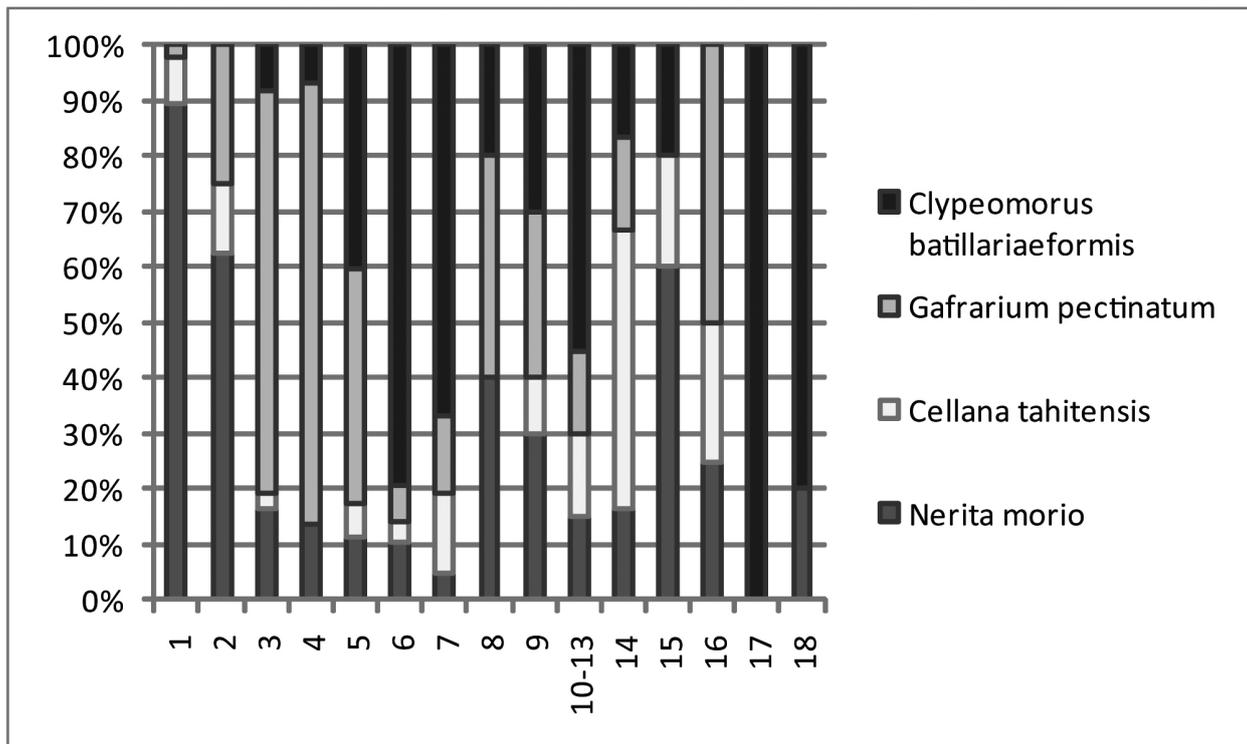
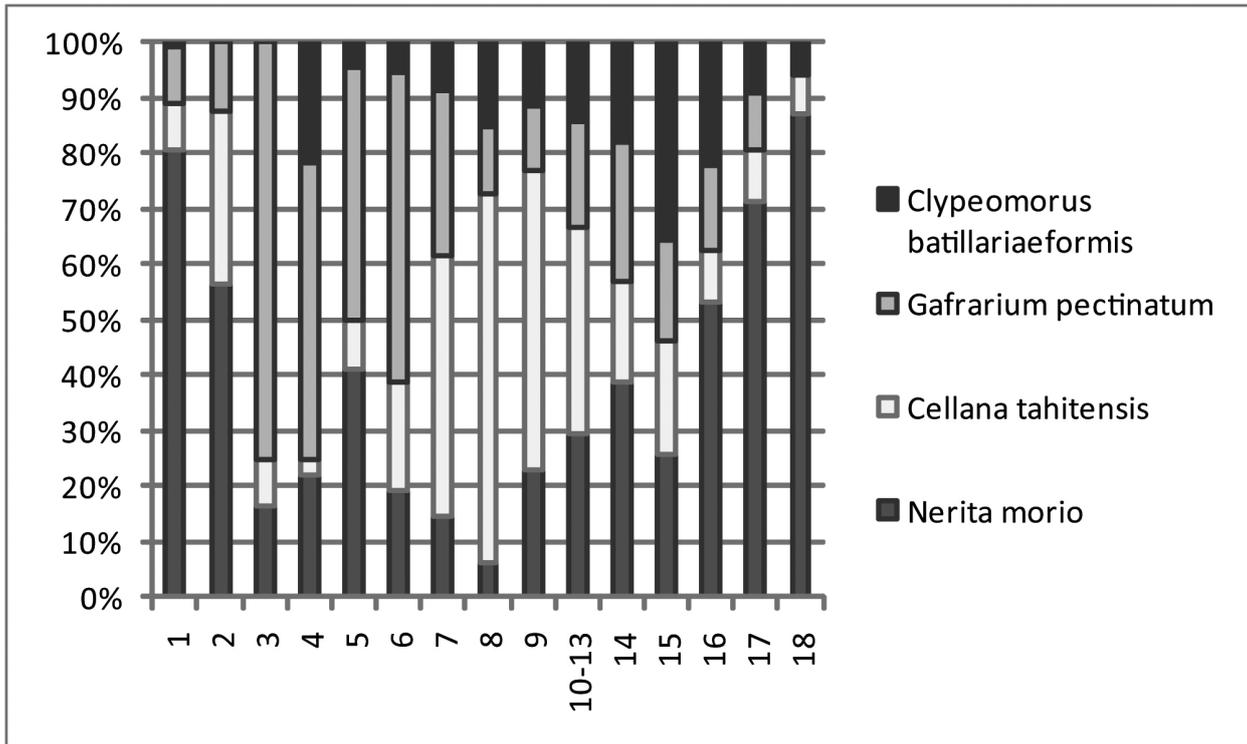


Figure 9.5. Percentage graphs of the four major shell species in squares E1 (above) and E2 (below). Note that the E2 sample is generally smaller and below spits 10–13 is negligible.

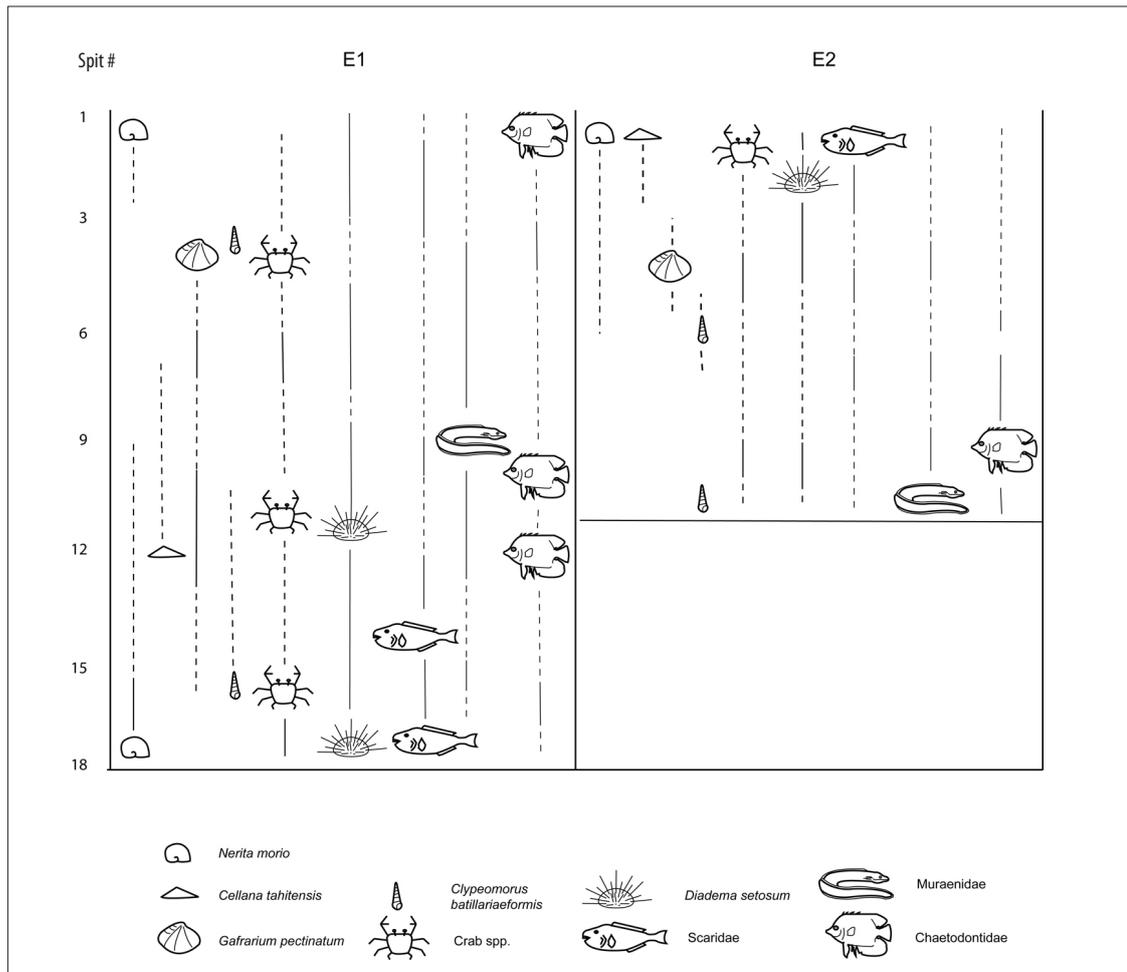


Figure 9.6. Schematic representation of abundances of major marine taxa represented in Tangarutu squares E1 and E2 by depth. Taxon picture placements indicate a high level of occurrence at that depth, with solid lines indicating a sustained presence and dotted lines indicating lower levels of occurrence.

in particular (Shunula and Ndibalema 1986; Dumas et al. 2007). A number of studies have also demonstrated that *Diadema* densities are considerably higher in impacted/fished inshore habitats than in protected, unfished areas (McClanahan et al. 1994; Carreiro-Silva and McClanahan 2001). Indeed, *Diadema setosum* is one of the most conspicuous inhabitants of heavily altered dynamite-fished coral-reef habitats (KS pers. obs.).

Diadema remains are present throughout most of the Tangarutu sequence, although there are marked changes in frequency through time. In terms of the invertebrate record, the lowest urchin densities in squares E1 and E2 coincide with the dominance of the bivalve *Gafrarium tumidum* (see Figure 9.6), suggesting that Anarua Bay at these times hosted greater expanses of fine-grained soft sediments than was ordinarily the case. The highest densities of *Diadema* remains tend to occur with high levels of *Nerita morio* and/or *Cellana tahitensis* (see Figure 9.6), all affirming the presence and productiveness of micro-algal turfs in Anarua Bay through many parts of the early, middle and later Tangarutu sequence.

The strong showing of invertebrate taxa favouring algal environments is also reflected in the fish taxa present. Given the low numbers of identified fish relative to invertebrates, the small sample of fish taxa cannot be taken to present a comprehensive picture of inshore stocks or habitats. Nevertheless, a presence-absence approach to the occurrence of certain taxa at different depths, such as butterflyfishes and damselfishes, allows us to draw some conclusions regarding the nature

of inshore niches at particular times in Anarua Bay. Algal-grazing fish taxa dominate the Tangarutu assemblage, with grazing taxa including scarids, pomacentrids and chaetodontids, supplemented by the fluctuating presence of serranids and the more consistent presence of eels in the Muraenidae and Congridae. While there are 13 species in the Chaetodontidae known from Rapa, the only species-level identification provided by Randall and Sinoto (1978) is *vaiti/C. smithi*, which is known to aggregate in areas of algae-covered rocky reefs (Lieske and Myers 1994). As previously discussed, both *komokomol L. vaigiensis* and *ngangal S. fasciolatus*, associated ethnographically with the candlenut fish hooks, also inhabit areas of abundant algal growth.

Collectively, the fish, urchin and shell data from Tangarutu suggest that Anarua Bay supported extensive hard-substrate habitats, which in turn supported substantial non-crustose micro-algal turfs. However, the oscillations in the frequencies of different algal-grazing mollusc taxa, grazing *Diadema* urchins and fish taxa hint that parallel changes may have occurred in the structure and extent of these local algal turfs. A closer look at the ecological literature on tropical marine algal-grazing communities offers some insights into how community structure can be altered in the face of rather subtle changes or disturbances – including by fishing.

As might be expected, various of these algivorous creatures compete with each other – sometimes aggressively. *Stegastes* spp. are known collectively as ‘farmer damselfish’, as they carefully maintain and ‘weed’ patches of non-crustose algae in a territory that they defend vigorously (Russ 1987). While microalgal-grazing molluscs may be tolerated in *Stegastes* territories, *Diadema* urchins are not (Lieberman et al. 1984; Klumpp and Polunin 1989). Similarly, *Stegastes* may patch-share with acanthurids, which are poorly represented in the Tangarutu sample, but will ward off scarids. Given that in some zones of the Tangarutu deposits quantities of *Diadema* and pomacentrid remains occupy the same stratigraphic position (e.g. the upper spits of E1), it would appear that distinct, non-overlapping zones of the rocky reef are being exploited by the local residents. But the ecological literature suggests that such discrete zones are likely to change in extent and community composition through time.

Grazing strongly effects the distribution of algal species (Lieberman et al. 1984; McClanahan et al. 1994). This is especially the case where grazers selectively target algal taxa that do not dominate in biomass terms (Hatcher and Larkum 1983). Pomacentrids will selectively remove non-favoured algae from their territories, thus increasing the biomass of favoured species (Klumpp and Polunin 1989), while intensive urchin grazing promotes algal growth, keeping the standing crop trimmed, thereby decreasing ‘self-shading’ (Klumpp and McKinnon 1989). It stands to reason that the removal of algal grazers in any numbers, whether urchins, fish or even numbers of grazing molluscs, will impact on the growth rate and taxonomic composition of algal communities, and indeed such effects have been demonstrated.

The above discussion stresses natural processes and indirect human impacts that may be contributing to changes in exploited marine resources through time at Tangarutu. However, we also know that the forms of human impacts themselves were changing. The late-stratigraphic association of the candlenut fish hooks demonstrates tangibly that fishing technologies transformed through time, and this might be expected to have had an impact on the landed assemblage.

The subtle oscillations through time in the community structure and balance of algal-grazing herbivorous marine taxa, both vertebrate and invertebrate, suggest that environmental and habitat parameters were also constantly shifting. Some of this variability may relate to strictly environmental factors such as variations in storm frequency, wave intensity and cycles of erosion and progradation. However, the marine ecology literature would suggest that high levels of occurrence of the urchin *Diadema setosum* are likely to be the product of at least moderate

human fishing pressure on marine communities within Anarua Bay (see McClanahan et al. 1994; Carreiro-Silva and McClanahan 2001). Although it is presumed that the rise in *Diadema* densities in tandem with fishing pressure was largely due to the removal of urchin predators in the system (e.g. McClanahan 1998), it is also likely that the greater availability of food following the removal of herbivorous algal-grazing fish, particularly within the Scaridae, Acanthuridae and Pomacentridae (Foster 1987), promoted growth in urchin populations.

In a similar vein to the relationship between fish and urchin population structure and abundance, the relationship between levels of crayfish (*Panulirus pascuensis*) exploitation and urchin abundance may turn out to be linked. A link between heavy exploitation of the urchin predator *Panulirus* and a rise in urchin numbers has been established (Tegner and Levin 1983). At present, this relationship cannot be assessed from the Tangarutu sample; species-level identification of the crustacean remains would be required.

High levels of *Diadema* urchin grazing have been found to alter significantly the composition of organisms that compete with algae (Sammarco 1980, 1982). Not only is coral recruitment hindered by urchin grazing, but the diversity of fleshy algae, polychaete worms, encrusting coralline algae, filamentous greens and foraminifers is reduced, with some groups being virtually excluded (Sammarco 1980). This scenario has flow-on implications for the structure and composition of herbivorous vertebrate and invertebrate communities, as well as for those creatures that prey on them.

The consistent presence, and even more so the sporadically high abundance, of *Diadema setosum* remains within the Tangarutu deposit indicates that Anarua Bay was not only subject to fishing pressure, but that the various trophic levels and competing species within them were constantly adjusting to intra-community and environmental pressures. The respective roles of grazing gastropods, urchins, crustaceans, eels and various species of herbivorous and predatory fish in the Anarua system varied as different species and classes jostled for survival and dominance.

Humans and marine resources at Anarua Bay

The archaeological and ethnographic records offer some insights into how humans impacted this dynamic ecosystem through time. The relationship between densities of *Diadema* urchins and fishing pressure has been discussed above, but an argument for depletion of the standing stocks of Scaridae due to overfishing in the early part of the sequence could perhaps be advanced. This family is present throughout the sequence, though it is probable that the species targeted changed through time. The ethnographic data for differing capture methods for different species of scarid provided by Stokes (n.d.) and the increase in Scaridae at the end of the sequence, concurrent with the appearance of the candlenut fish hooks, would tend to support this.

Overall, the picture of marine resource use by the occupants of Tangarutu shelter through time is one of flexibility. Resource-switching is frequent, probably reflecting concomitant changes in inshore habitats and resources. Strategies employed for food capture seem to be general enough that a wide range of taxa is accessible at any given time, yet flexible enough to allow such resource-switching if local marine conditions and communities change. Both these facets of subsistence behaviour are also in evidence in the ethnographic record. The fish and eel capture technologies described by Stokes, as well as the roster of captured species, show that a balance was maintained between more generalist capture strategies, such as the use of weirs, nets and basket traps, and very targeted strategies, such as the use of candlenut hooks, to capture *Leptoscarus vaigiensis*.

A closer comparison of the archaeological and ethnographic records also reveals that resource-switching in a Rapan context was not always simply a matter of economic expediency – at least

it is not always explained as such. As noted by Stokes, many of the species of mollusc seen by locals as 'inedible' were abundant in midden deposits. Eels feature prominently in the assemblage from Tangarutu throughout the sequence, and are also present in the assemblage from Akatanui 3. Sharks, while low ranking in terms of relative abundance, are also present in both assemblages. The capture of both eels and sharks was still in evidence during the time Stokes (n.d.) collected his ethnographic data. However, the information collected by AA during the 2002 field season indicates that neither sharks nor eels are taken today. Rapans consider shark repugnant and eels tapu. Thus, shifts in resource procurement and consumption also appear to have a cultural dimension, with ideas about food sources changing markedly through time.

Conclusion

In the two-way traffic of human-environmental interactions seen at Anarua Bay there occurred active modifications in traditional Polynesian ways of life. Many of the resources so important elsewhere in Polynesia were not available to Rapans, and new strategies and solutions had to be consciously developed. Such creative problem solving is clearly evidenced in the Tangarutu fish-hook assemblage, where traditional working techniques are applied to novel materials. A further potential way of solving the problem of the lack of availability of traditional raw materials would have been to import them – a solution seen elsewhere in Polynesia (Weisler 1993). There is no evidence that such action was ever pursued by Rapans.

Cultural innovation can typically be understood as a creative reconfiguration of traditional practice; ideas do not emerge from nowhere, but from the knowledge base already present in a given society (e.g. see Bijker 1987; Hickman 1995). As such, innovation often represents incremental change rather than a complete disjuncture (Kroeber 1948:360). Thus, while the candlenut fish hooks recovered from Tangarutu appear as a cultural novelty, they have strong technological parallels with traditional Polynesian fish-hook manufacture in other materials.

Technological innovations do not follow trajectories, but rather *create* them (Bijker and Law 1992; Szabó 2005:93), and given the late provenance of the Tangarutu hooks it appears that developing solutions to living in a Rapan environmental context was an ongoing and reciprocal process between population and environment (Kennett et al. 2006) throughout prehistory.

Notes

1. Juvenile specimens of *Pinctada margaritifera*, with a maximum width of ca. 12 mm, have been recorded in the Tangarutu shell midden, but there is no indication that specimens of the size and robusticity required for fish-hook manufacture were locally available.
2. Several crayfish mandibles were seen during excavation at E1 and E2, Tangarutu, but they were not identified in the retained samples.

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