

Traditional Rotuman Fishing in Temporal and Regional Context

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ABSTRACT Few archaeological sites in the central western Pacific (i.e., Fiji–Samoa–Tonga region) have provided large and temporally well-controlled archaeofaunal assemblages. Therefore, three sizable Rotuman assemblages, dating to the ca. 7th–11th century AD, provided an opportunity to improve our understanding of the region's traditional fishing practices. The assemblages are analysed in terms of taxonomic composition, abundances, and ecological associations of the taxa. Indications are that the foraging range and intensity of Rotuman fishing may have declined through time, although the results from this single site are interpreted with caution. Comparison with other Pacific assemblages suggests that this may be a common trajectory, one which is to varying degrees intertwined with agricultural intensification, the growth of animal husbandry systems, increased competition, and possibly resource depression. Copyright © 2001 John Wiley & Sons, Ltd.

Key words: fishing practices; zooarchaeology; subsistence change; Rotuma; central Pacific

Introduction

There have been few detailed archaeofaunal studies in West Polynesia, an area which we define to include the islands of Samoa, Tonga, Fiji and Rotuma on biogeographic and cultural grounds (see below). The reasons for the limited analyses are varied, including past problems of poor recovery, poor preservation, a lack of comparative collections, and in some cases simply a lack of interest in archaeofaunal remains. We report here on three vertebrate assemblages from Rotuma Island composed primarily of fish. Significant in size, but from a relatively short period of time, the Maka Bay archaeofauna materials open the window to Rotuman subsistence practices in the 7th–11th century AD. Moreover, when viewed in the larger central Pacific context, the Rotuman assemblages contribute to our understanding of changing fishing practices across the region.

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The Rotuman ecological and cultural context

The isolated island of Rotuma lies 465 km northwest of the Fijian Archipelago, its nearest neighbour being another small island, Futuna, 385 km to the east (Figure 1). The Rotuman mainland is a 42 km² basaltic shield volcano of Pleistocene age which rises to 255 m above sea level. Two large bays dominate the western end of the island, Maka Bay to the north and Hapmafau Bay to the south, the site of interest here lying on the western end of the former (Figure 1). Oral histories, archaeological data, and geological evidence indicate that the narrow isthmus between these bays formed in the relatively recent past (Howard, 1970, 1985; Woodhall, 1987; Ladefoged, 1993a). Prior to the closure of the isthmus, Maka Bay was probably both deeper and more regularly flushed with fresh sea water.

Physically nearly midway between Melanesia, Micronesia and Polynesia, linguistic evidence (Pawley, 1996) suggests that Rotuma was settled

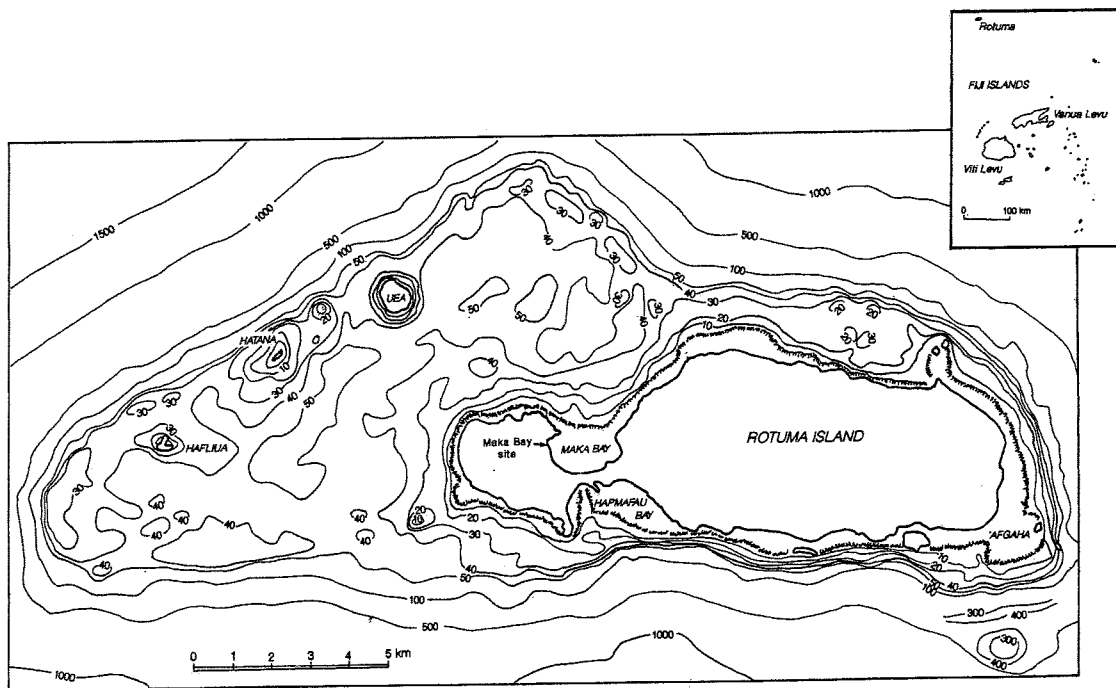


Figure 1. Rotuma Island and local bathymetry (adapted from Woodhall, 1987).

by Lapita colonists at the same time as Fiji, Samoa, and Tonga, roughly 3000 years ago; however, archaeological deposits dating to this period have yet to be identified. Additionally, both linguistic and archaeological evidence point to interaction with Fiji, Tonga and Samoa in the late prehistoric period (Gardiner, 1898; Biggs, 1965; Shutler & Evrard, 1991; Ladefoged, 1993a,b; Pawley, 1996; Wall, 1997). Contact with Fiji in particular dates to the 10th to 11th century AD, as indicated by provenance studies of the Maka Bay ceramics (Ladefoged *et al.*, 1998). Given the presumed common colonization history of Rotuma by Lapita pottery-bearing populations, a shared biogeography, and evidence for post-settlement interaction with Fiji, Samoa, and Tonga, we refer to these islands generally as West Polynesia.

Today much of the mainland vegetation is anthropogenic in character. The only remaining native forest is found on the 200 m high peak of Solhoi (McClutche, personal communication to Ladefoged, 1991). The extant native land fauna is limited to nine lizards, 15 land and seabirds, and two bats (Clark, 1982; Clunie, 1984, 1985; Watling, 1985; Zug, 1991). The

local marine fauna is poorly known but includes at least 425 species of fish (Zug *et al.*, 1988). At western contact, both the Pacific rat (*Rattus exulans*) and domesticated pig (presumably *Sus scrofa*) were present. However, there are no historic indications of use of the former as a food source, in contrast to some other Polynesian localities.

A detailed survey by the Fijian Fisheries Division (1983) identified four marine environments of interest here: (1) a well-developed but generally narrow (less than 400 m wide) fringing reef and reef flat; (2) the 'shallow' (less than 18 m) lagoon of Maka Bay; (3) a 18–64 m deep submarine shelf, narrow in most places but extensive on the north-to-west side of Rotuma where it covers a roughly 180 km² area; and (4) the outer edge of this submarine bank, an area which is a particularly productive ground for lutjanids (snapper) and lethrinids (emperor fishes). Several small uninhabited volcanic islands are found around the main island (Figure 1). Uea and Hafliua Islets, to the west of the main island, lie on the edge of the extensive sand and coral bank and are occasionally used by marine foraging parties (Fijian Fisheries

Division, 1983). The submarine bank itself is the deposit of an older atoll reef which developed on a Tertiary volcanic platform (Woodhall, 1987). West of this feature lies Whale Bank, a second submarine feature of ca. 6 km².

The modern fisheries survey also provides a profile of local fish populations. Herbivores such as acanthurids and scarids were common in the inshore areas, while carnivores such as seranids and lutjanids were rare (Fijian Fisheries Division, 1983). The authors comment that it was unclear whether these patterns reflected the natural ecology of the island or heavy fishing pressures. The outer edge of the northwest submarine bank was noted as the most productive habitat, one favoured by modern Rotumans, as also observed more recently by Ladefoged. Along the northern edge of the bank, the fish survey encountered a large 'resource' of lethinids, within ca. 25–35 fathoms (46–64 m) (Fijian Fisheries Division, 1983). Good catches of lutjanids were found in these deeper waters as well, particularly off the southeast and northeast points of the island; this taxon was more limited along the northern edge of the bank.

Inside the reef there are relatively few areas with enough depth and appropriate substrates for large gill netting; one of the better spots is within Maka Bay where catches of roughly 50 kg were typical (Fijian Fisheries Division, 1983). The authors observed that the composition of their catches here differed markedly from those obtained in similar environments in Fiji. Among the Maka Bay dominants were mullids (goatfish), albulids (bonefish), and *Caranx* spp. (trevally).

A variety of fishing techniques were used traditionally. The unpublished early 20th century study of MacGregor (1932) indicates an emphasis on inshore environments. A number of netting technologies, poisoning, spearing, woven fish traps, and stone weirs were used (see also Boddam-Whetham, 1876). Among the more unusual strategies was the use of a ball of charcoal-stained spider web to catch garfish (Hemiramphidae—probably *Hyporhamphus* sp). In the ethnographic accounts, line fishing receives minor attention—and was principally associated with snapper (*rona*) and shark (*i'oro*) fishing in deeper waters off the submarine bank.

MacGregor's (1932) informants described hooks made from ironwood wood, turtle shell, and more unusually, fish vertebrae and a 'hardwood' which was known as *aeiva* and was collected from deep water areas by diving. The emphasis on inshore technologies in general, and netting in particular, is consistent with other West Polynesian ethnographic accounts (e.g. Kirch & Dye, 1979; Kirch, 1984).

The Maka Bay excavations

Maka Bay, lying to the lee of the southeast trade winds, is one of the most protected areas on the island (Figure 1). The bay measures ca. 2 km across, with a fringing reef extending across its mouth, ca. 1 km from the shoreline. A discontinuous sandy apron is found around the edge of the bay. The Maka Bay Site is located on the northwest end of the bay, midway between Itu'muta and Maftoa Village. It lies ca. 30 m inland from the high tide mark at ca. 2 m elevation (Figures 1 and 2). Adjacent to the home of Mr. Jiare Vafo'ou, the site is today covered in low grass. The cultural deposits were initially identified through a coring programme carried out in 1991 by Ladefoged (1993a). In 1996, coring was further used to determine the extent of the site and areal excavations were undertaken by Ladefoged and Wall. Twelve square metres were excavated using hand trowels (Figure 2) and processed with 6.4 mm (1/4 inch) and 3.2 mm (1/8 inch) screens. All vertebrate materials recovered from the screens were retained. Bulk samples of the invertebrate remains were obtained from 25 × 25 cm baulks of each excavation unit and processed in the field laboratory with 3.2 mm screens.

Three major prehistoric stratigraphic zones were distinguished, all sandy clay loams (Figure 3; see Wall, 1997 for sedimentary details):

- Upper Zone: ca. 25–55 cm below surface;
- Middle Zone: ca. 50–70 cm below surface;
- Lower Zone: ca. 70–110 cm below surface.

These cultural sediments were capped by a ca. 15 cm thick historic stratum and rested on a basal sterile clay.

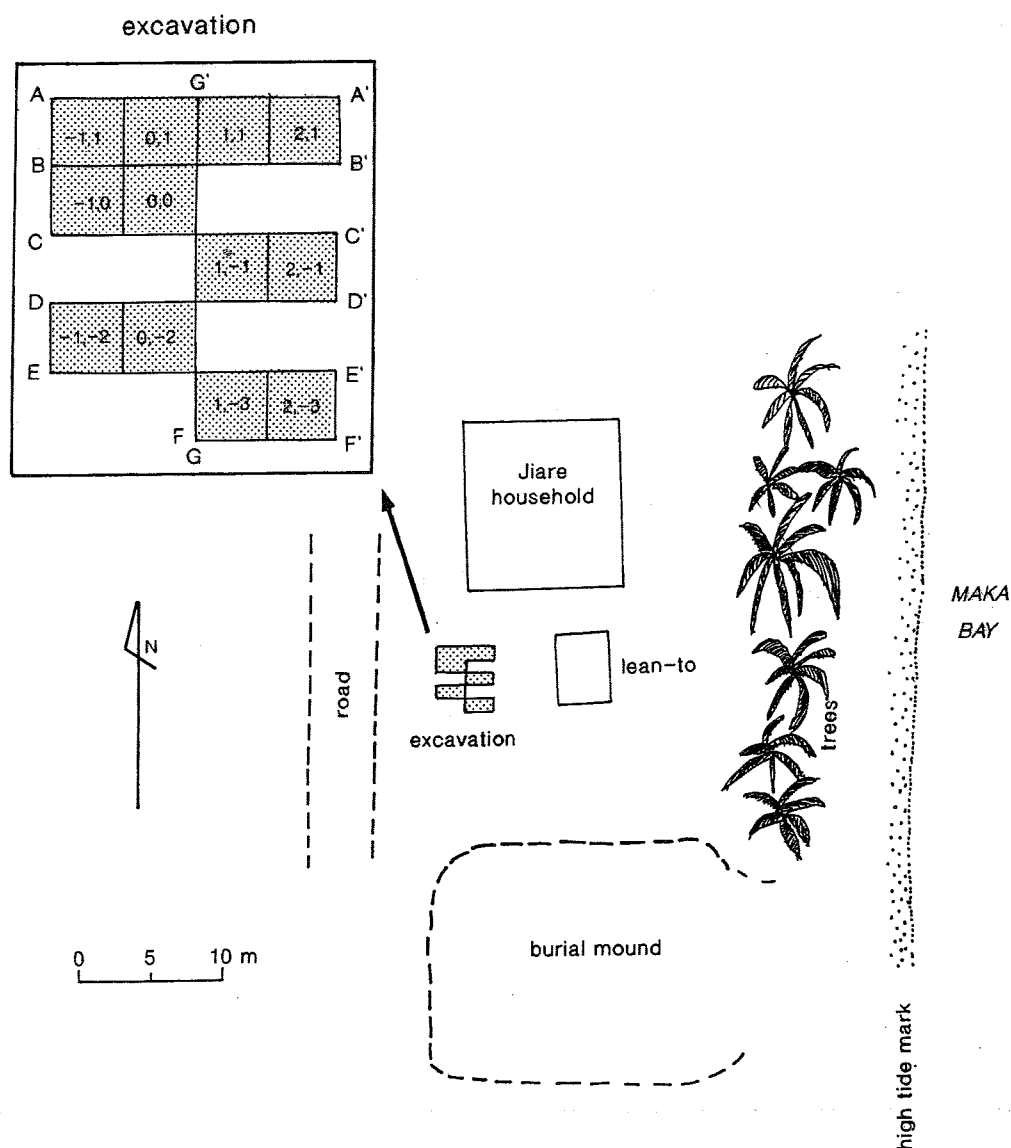


Figure 2. Maka Bay site plan view and excavation layout.

Three radiocarbon dates, two from the Lower Zone (B-098659 on rat bone and B-098660 on wood charcoal) and a third from the Upper Zone (B-106883 on wood charcoal), suggest initial occupation of the site was most likely in the 7th or 8th century AD and abandonment in the 10th or 11th century (Figure 4) (see also Ladefoged, 1993a; Ladefoged *et al.*, 1997; Wall, 1997). The site thus represents between 400 and 200 years of settlement on this coast. If the assumption of colonization during the Lapita

cultural horizon is upheld, then occupation at the Maka Bay site may date to as much as 1750 years after initial settlement of the island.

In the remainder of this paper we compare the fish remains from the three prehistoric occupations in terms of their ecological and economic implications. We suggest that comparisons between these strata are valid for several reasons. First, the functional equivalence of the three occupations is independently suggested by the associated artifact assemblages,

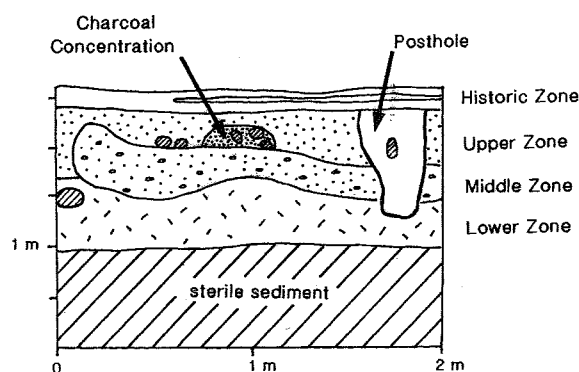


Figure 3. Northeast profile of excavation unit -1,1.

which include pottery, shell adzes, coral abraders, and worked shell (see details in Wall, 1997). Functional equivalence is further indicated by the features of the three zones, which include hearths and ovens, post-molds, and pits. The combination of the artifacts and features from the three zones is consistent with domestic activities, while the post-molds suggest activities of at least a semi-permanent nature. Overall, no major change in site function during the period of occupation is apparent, such as might be responsible for altered patterns of fish deposition.

The three zones also are similar with regards to the depositional processes which have led to their accumulation—primarily low energy wind deposition and surface run-off, augmented by the activities of people and possibly some occasional storm deposition, although no distinct storm deposits were apparent in excavation. Finally, the three zones have been affected by

similar post-depositional processes—probably most importantly comparable weathering conditions. Given the foregoing, we suggest that changes in the three faunal assemblages are most likely the result of changes in faunal use rather than major changes in site function or taphonomic conditions.

Faunal samples and methods

The Maka Bay excavation produced a faunal sample of 4699 identifiable vertebrate specimens, of which 3033 were bony and cartilaginous fish (Tables 1 and 2). Also represented were, in descending order of abundance, rat (*Rattus cf. exulans*), domestic pig (*Sus cf. scrofa*), human (*Homo sapiens sapiens*), dolphin (Delphinidae), sea turtle (Cheloniidae), bird (taxa undetermined) and dog (*Canis familiaris*) teeth (quite possibly imports) (Wall, 1997). Only rat was represented in large amounts (NISP = 1479, MNI = 216). Additionally, ca. 40 kg of shellfish remains were obtained from the 25 cm² baulks (Wall, 1997).

We report here on a sample of the fish remains derived from four contiguous excavation units: Unit -1,1; Unit 0,1; Unit -1,0; and Unit 0,0 (see Figures 2 and 3). Vertically, the samples come from 10 cm excavation levels within the middle of each stratigraphic zone and all were processed with 3.2 mm screens. We have focused on these stratigraphically most secure samples in an effort to distinguish temporal patterning across the three zones with the

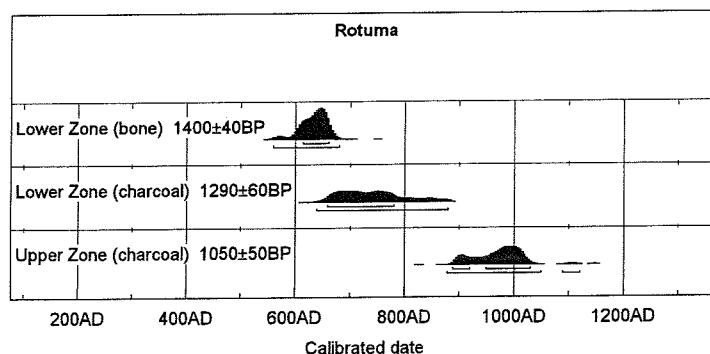


Figure 4. Maka Bay radiocarbon dates. Conventional radiocarbon ages are shown for each sample; probability distributions and ranges were derived from OxCal Program v. 2.18 based on Stuiver & Kra (1986).

Table 1. Characteristics of archaeologically recovered Rotuman fish taxa

Scientific name	Common name	Preferred habitats ^a	Dietary preferences ^b	Capture technologies ^c
Acanthuridae	Surgeonfishes	RF	H	N, S, P, A
Aulostomidae	Trumpetfishes	OR, RF	P	No data
Balistidae	Triggerfishes	RF, LA, OR	O/BC	N, P, A
Carangidae	Trevallies	RF, PAS, OR	P	A, N, S
Diodontidae	Porcupinefishes	RF, OR	O/BC	A, TR, N
Elasmobranchii	Cartilaginous fish	LA, PE, OR	P	A, S, N
Ephippidae	Batfishes	LA, OR	O/BC	No data
Gerreidae	Silver Biddies	RF, LA	O/BC	N
Holocentridae	Soldier/Squirrelfishes	RF, OR	O/BC	A, S, P
Kyphosidae	Drummers	RF, LA, OR	H	S, A, N
Labridae	Wrasses	RF, LA, OR	O/BC	A, S, N, P
Lethrinidae	Emperors	RF, OR	O/BC	A, N, T
<i>Monotaxis grandoculis</i>	Big-eye Bream	RF, OR	O/BC	S, P
Lutjanidae	Snappers	RF, LA, OR	P	A, N, S, P
Mylobatidae	Eagle Rays	RF, OR	O/BC	A, N, S
Mullidae	Goat fishes	RF, PAS	O/BC	N, A, P
Muraenidae	Morays	RF	P	S, P, TR
Ostraciidae	Boxfishes	RF, LA, OR	O/BC	S, P, N
Scaridae	Parrotfishes	RF, OR	H	N, S, TR
Scorpaenidae	Scorpionfishes	RF, LA, OR	P	P
Scombridae	Tunas and mackerels	PE, LA	P	T, A, S, N
Serranidae	Rockcods or groupers	RF, OR	P	A, N, TR, T, S, P
Sphyrnidae	Barracudas	OR, PAS, LA	P	A, T

^a Habitat classes: inshore: RF, reef flat; LA, lagoon; offshore: OR, outer reef; PAS, passes; PE, pelagic (from Allen, 1992a, table 8.23).

^b Diet classes: H, herbivore; O/BC, omnivore/benthic carnivore; P, piscivore; Z, zooplankton feeder (from Allen, 1992a, table 8.23, as summarized from Myers, 1989 and Randall *et al.*, 1990).

^c Fish capture technologies: S, spearing; N, netting; A, angling; P, poisoning; T, trolling; TR, trapping (from Allen, 1992a, table 8.23 and references therein).

greatest possible accuracy; the drawback of this approach is a reduction in sample sizes.

The recovered fauna were identified by Wall using comparative collections of the Department of Anthropology, University of Auckland and the Archaeozoology Laboratory at Te Papa. The Museum of New Zealand; the assistance provided by Dr Foss Leach of Te Papa to Wall in this process is much appreciated. Most of the identifications are based on five diagnostic mouth elements of bony fish: premaxilla, dentary, articular, maxilla, and quadrate (see Leach, 1997, 1986). In addition, a small number of elements which are diagnostic for a limited number of families, sometimes called 'special bones' (after Leach, 1986), were identified.

To maximize comparison with other Pacific assemblages, both the number of identified specimens (NISP) and the minimum number of individuals (MNI) (as defined by Leach, 1986) are provided in Tables 2 and 3. Also of importance are the differing biases associated with the

two measures (Grayson, 1984). NISP can be a poor measure of abundances in contexts where the assemblages are highly fragmented. However, if the taphonomic histories are consistent across strata, as we suggest for Maka Bay, then comparisons of changing relative abundances would be meaningful. MNI, in contrast, can be strongly affected by the way samples are divided or aggregated (e.g., by levels, layers, site, etc.). Application and comparison of both measures allows these biases to be evaluated within a given assemblage.

The three zonal assemblages that are the focus of this paper provided 652 specimens. Fifteen families of bony fish representing at least 16 taxa were recovered from the zone samples, along with remains of cartilaginous fish (i.e. sharks and rays) (Tables 1–3; systematics follow Nelson, 1994 and Randall *et al.*, 1990). Another five families of bony fish are represented in the site at large by small numbers of specimens (see Table 2).

Table 2. Zone samples and total site assemblage, five paired head bones and 'special' bones (NISP and MNI)

Taxon	Upper Zone		Middle Zone		Lower Zone		Total Maka Bay	
	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Acanthuridae	1	2	2	4	1	2	11	37
Aulostomidae	—	—	—	—	—	—	1	2
Balistidae	1	3	4	8	5	6	61	89
Carangidae	—	—	1	2	3	7	11	34
Diodontidae	1	2	1	31	1	10	2	270
Elasmobranchii vertebrae	1	5	1	12	1	9	1	116
Lamniformes teeth	—	—	1	1	1	1	1	11
Mylobatidae barbed spine	—	—	—	—	—	—	2	2
Ephippidae	—	—	1	1	—	—	1	1
Gerreidae	—	—	—	—	—	—	2	2
Holocentridae	2	3	7	23	6	19	36	198
Kyphosidae	—	—	—	—	—	—	1	2
Labridae	7	8	5	22	9	50	127	320
Lethrinidae	2	5	9	33	11	46	52	241
<i>Monotaxis grandoculis</i>	1	2	4	7	3	4	14	43
Lutjanidae	1	1	3	10	5	14	12	52
Mullidae	—	—	1	1	—	—	2	4
Muraenidae	—	—	—	—	2	2	2	7
Ostraciidae	1	2	1	42	1	20	2	237
Scaridae	11	38	32	133	11	66	211	1092
Scorpaenidae	—	—	—	—	1	1	3	8
Scombridae	—	—	—	—	—	—	1	2
Serranidae	1	4	8	33	10	37	48	262
Sphyraenidae	—	—	—	—	—	—	1	1
Totals	30	75	81	363	71	294	605	3033

Table 3. Zone samples and total site assemblage, five paired head bones (NISP and MNI)

Taxon	Upper Zone		Middle Zone		Lower Zone		Total Maka Bay	
	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP
Acanthuridae	—	—	2	3	1	2	6	15
Aulostomidae	—	—	—	—	—	—	1	2
Balistidae	2	2	2	3	1	2	8	28
Carangidae	—	—	1	2	3	7	11	34
Diodontidae	—	—	1	1	—	—	2	3
Ephippidae	—	—	1	1	—	—	1	1
Gerreidae	—	—	—	—	—	—	2	2
Holocentridae	2	3	7	23	5	18	36	198
Kyphosidae	—	—	—	—	—	—	1	2
Labridae	1	1	5	11	6	31	32	130
Lethrinidae	2	5	9	33	11	46	52	241
<i>Monotaxis</i>	1	1	4	7	3	6	14	43
Lutjanidae	1	1	3	10	5	14	12	52
Mullidae	—	—	1	1	—	—	2	4
Muraenidae	—	—	—	—	2	2	2	7
Scaridae	11	22	17	48	10	38	146	520
Scorpaenidae	—	—	—	—	1	1	3	7
Serranidae	1	4	8	33	9	36	48	262
Sphyraenidae	—	—	—	—	—	—	1	1
Totals	21	39	61	176	57	203	380	1552

Table 3 provides counts, NISP and MNI, of the recovered taxa, as based on the five diagnostic bones, while Table 4 provides the rank order abundances of the nine most abundant taxa. Comparison of the rank orders, using Spearman's rho rank order correlation coefficient,

Table 4. Zone assemblages: rank order abundance of most common fish families by NISP and MNI (five paired head bones only)

Taxon	Upper Zone		Middle Zone		Lower Zone	
	MNI	NISP	MNI	NISP	MNI	NISP
Scaridae	1	1	1	1	2	2
Lethrinidae	2	2	2	2	1	1
Serranidae	6	3	3	3	3	3
Holocentridae	3.5	4	4	4	5.5	5
Balistidae	3.5	5.5	7.5	7.5	8.5	8.5
Labridae	6	5.5	5	5	4	4
Lutjanidae	6	7	6	6	5.5	6
Acanthuridae	—	—	7.5	7.5	8.5	8.5
Carangidae	—	—	9	9	7	7

indicate that in all cases the two measures are highly correlated and significant at the 0.01 level (Table 5). This suggests that NISP and MNI are essentially measuring the same quantitative properties of each assemblage and, by extension, that neither fragmentation nor the way the assemblages were aggregated are adversely affecting assemblage abundances. Having demonstrated strong correlations between NISP and MNI values for the Maka Bay assemblages we elect to use NISP, the larger and underived value, in the remaining discussions, unless otherwise indicated.

Not unexpectedly inclusion of the 'special bones' lowers the correlation coefficients (Table 5) (see also Allen, 1992a; Nagaoka, 1994). This is because many of the special bones are elements which may be quite abundant on a single individual (e.g. *Diodon* body spines, Ostraciidae bony scales, shark teeth, and Elasmobranchii vertebrae) and as such they inflate the NISP values relative to those of MNI. Other taxa, such as scarids and labrids have additional elements which are highly diagnostic, namely three pharyngeal plates (two upper and one lower), which may lead to their better representation and increases in both NISP and MNI for those taxa. The Maka Bay comparisons provide

additional support for excluding special bones in inter-taxonomic comparisons of relative abundance. However, as Allen (1992a) discusses in detail, these 'special bones' are critical to evaluating assemblage richness or diversity, as some species may only be represented by these elements. The Maka Bay comparisons also highlight the need to consider how abundances were calculated when making cross-regional comparisons.

Modified faunal remains

Two large Balistidae fish teeth were culturally modified (Figure 5(A)), one with a completely perforated root and the another partially drilled. The modifications suggest that these specimens were intended for use as ornaments. Drilling of teeth is common in Polynesia, including those of dog, pig, dolphin, sharks and fish (e.g. Davidson, 1987; Walter, 1996). However, to our knowledge this is the first report of balistid teeth being used in this manner. A *Naso* caudal tang was also modified, drilled through the distal end, probably also for use as an ornament (Figure 5(B)). Again, we are unaware of other similar Pacific examples of this artifact type.

Table 5. Correlations of rank order abundances provided by NISP and MNI, with and without special bones (2-tailed test)*

	Upper Zone	Middle Zone	Lower Zone
Five paired bones r_s	0.98	0.99	0.99
Five paired bones + special bones r_s	0.93	0.72	0.83

* All comparisons are significant at the 0.01 level.

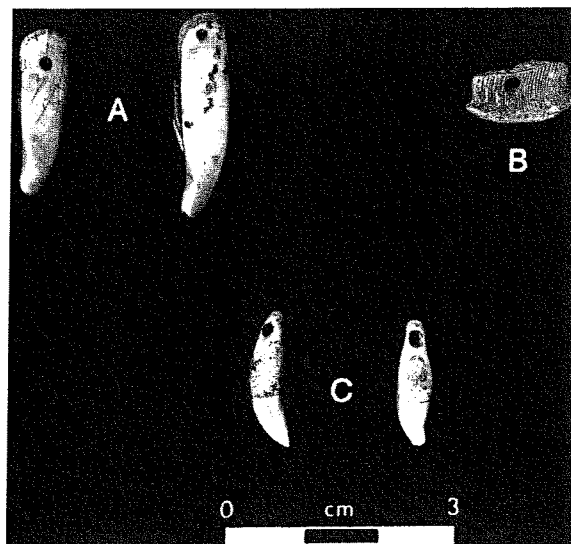


Figure 5. Maka Bay artifacts: (A) drilled Balistidae teeth; (B) drilled *Naso* caudal tang; (C) drilled mammal teeth.

Analysis of the zonal samples

General patterns

Five families comprise most of the three Maka Bay assemblages: Scaridae (parrotfish), Lethrinidae (emperors), Serranidae (groupers), Holocentridae (soldierfishes and squirrelfishes) and Labridae (wrasses), while two other families (Balistidae and Lutjanidae) are important to varying degrees. While the same families are important throughout the 400–200-year period, some temporal patterns are suggested. Comparison of the six most common families indicates that the rank order abundances of the Middle and Lower, and Middle and Upper Zones, are not statistically different at the 0.05 level (Table 6). However, rank order abundances of the Upper and Lower Zones are not correlated, supporting the overall impression of change through time.

Table 6. Comparison of rank order abundances of the six most common families (based on NISP of five paired elements) by zone

Measurement pair	Spearman's rho
Upper Zone with Lower Zone	0.77
Upper Zone with Middle Zone*	0.94
Middle Zone with Lower Zone*	0.87

* Significant at the 0.05 level.

In the early Lower Zone, Lethrinids are the dominant taxa comprising Rank 1, with the distinctive genera *Monotaxis* being an important contributor (Table 4, Figure 6). Through time, however, lethrinids decrease in both relative

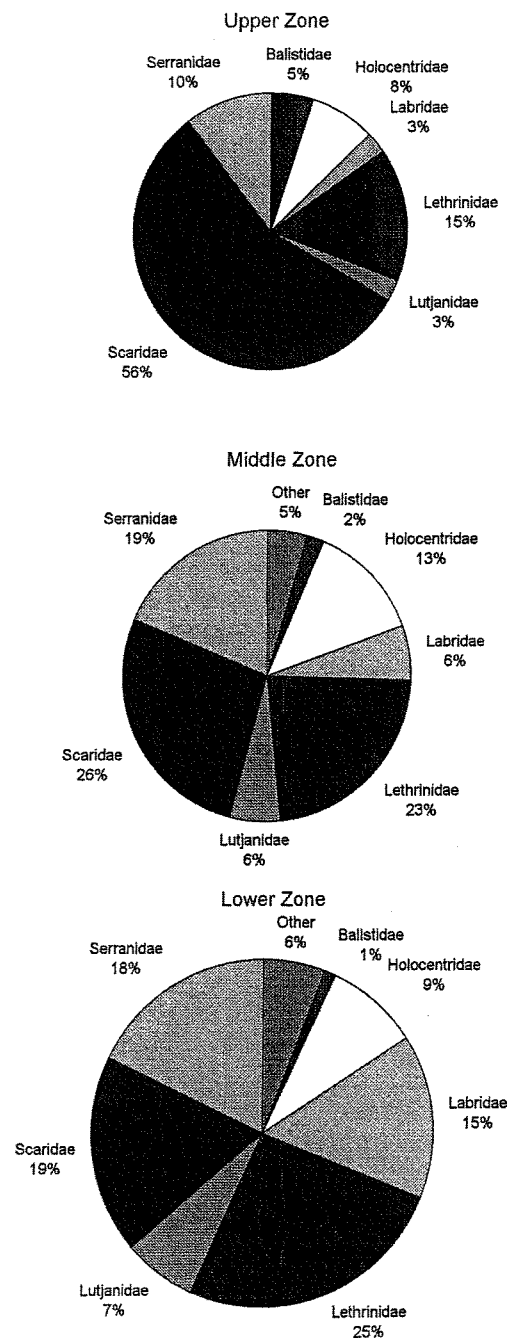


Figure 6. Relative abundance (based on NISP of five paired head bones) of most common fish families by zone.

abundance and in their rank order. In the Middle Zone, scarids dominate, assuming the top rank. Similarly, scarids dominate the Upper Zone assemblage, where they compose an even greater proportion of the assemblage (Table 4, Figure 6). As only the five mouth elements are being compared here (e.g., the particularly durable pharyngeals are excluded), the possibilities of artificial over-representation of this family are at least partially controlled. Patterning is apparent in some lower ranked taxa as well. For example, labrids assume a diminishing role through time, dropping from Rank 4 to 5.5 (15–3%), while balistids increase from Rank 8.5 to 5.5 (1–5%) (Table 4, Figure 6). To explore these patterns more fully, the fish were grouped by dietary preferences and habitats. These groupings admittedly overlook subfamilial diversity in both characteristics but serve a heuristic purpose.

Dietary preferences

Building from an approach used by Butler (1988, 1994) and Allen (1992a) we look first at fish dietary preferences which can be argued to underlie the use of particular fishing technologies. Three dietary classes were recognized in the present analysis:

herbivores which graze on algae and reef detritus and are usually taken with nets;

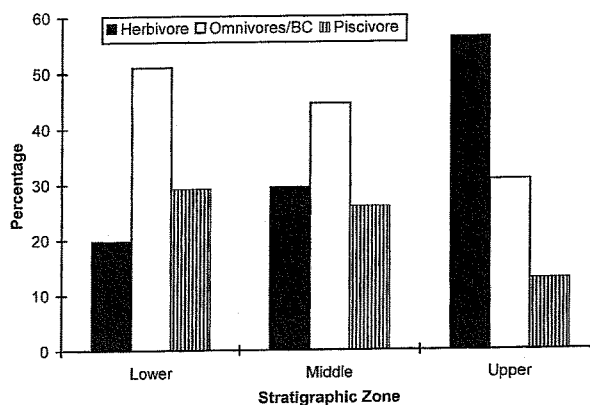


Figure 7. Relative abundance (based on NISP of five paired head bones) of ten most common fish families grouped by dominant dietary preferences.

omnivores/benthic carnivores which have diverse diets of marine plants, mollusks, echinoderms, and crustacea and which may be taken with nets or less commonly with baited hooks;

piscivores which pursue other smaller fish and most commonly are caught by angling, broadly defined here to include any techniques involving hooks and lures.

The rank order abundances of the ten top-ranking taxa of the three zones are compared in Figure 7 and Table 7. The graphs illustrate an overall pattern of declining proportions of

Table 7. Trends in Maka Bay fish families as shown by dietary preferences (rank order abundances of five paired elements)

Taxon ^a	Upper Zone NISP	Middle Zone NISP	Lower Zone NISP
Herbivores			
Scaridae	1	1	2
<i>Acanthuridae</i>	—	7.5	9
Omnivores and benthic carnivores			
Balistidae	5	7.5	9
Holocentridae	4	4	5
<i>Lethrinidae</i>	2	2	1
<i>Labridae</i>	6.5	5	4
Piscivores			
<i>Serranidae</i>	3	3	3
<i>Lutjanidae</i>	6.5	6	6
<i>Carangidae</i>	—	9	7
<i>Muraenidae</i>	—	—	9

^a Families in italics are those which decrease one or more full ranks between the Lower and Upper Zones; those in bold are families which increase and those in roman text are temporally stable taxa.

piscivores and omnivores/benthic carnivores. Within the piscivore group, the ranks change little, although Carangidae and Muraenidae are not represented in the two later zones. Notably, two pelagic fish, represented only in the larger site assemblage, were restricted to the Lower Zone: Scombridae (tuna) and Sphyraenidae (barracuda) (Wall, 1997). Within the omnivore/benthic carnivore group, some taxa increase noticeably (balistids) and others minimally (holocentrids), while lethrinids and labrids decrease, the latter markedly. It may be significant that these latter three families are often traditionally caught with baited hooks. Within the herbivores, scarids increase from Rank 2 to Rank 1 through time, while acanthurids decline. Overall, indications are that angling technologies may decline through time, but the evidence is far from conclusive.

Unfortunately, none of the recovered artifacts (Wall, 1997) directly support the apparent trends in fish remains. Fishhooks are generally rare in West Polynesian sites, the largest assemblage to date coming from To'aga where Kirch (1993) recovered 12 fishhooks and fragments. Maka Bay was no exception in this regard. Several perforated shells, found throughout the excavation, were suggested as possible net weights. However, in addition to their small size, there were also questions as to whether they were indeed culturally modified or drilled by natural predators (Wall, 1997).

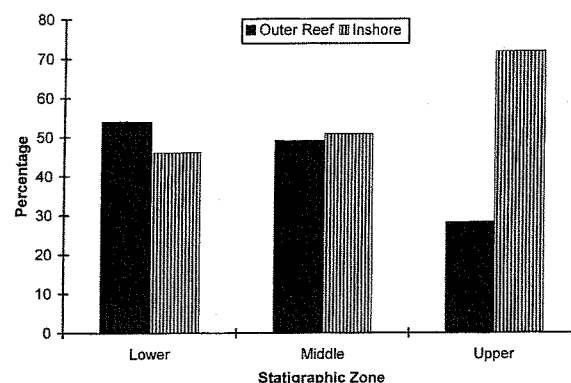


Figure 8. Relative abundance (based on NISP of five paired head bones) of ten most common fish families grouped by dominant habitat preferences.

Habitat preferences

Arraying the families by habitat highlights a further pattern (Table 8 and Figure 8). The abundance of inshore taxa increases in both relative and absolute terms. The rank order abundances of two taxa assigned to the outer reef or deeper waters decline through time, Lethrinidae and Carangidae. However, lutjanids and serranids remain stable (see Table 3). In contrast, the trends in inshore families are more variable. Those which increase include the scarids, balistids and holocentrids. In contrast, labrids decrease through time. The pattern suggests there may have been a decline in the frequency with which the outer reef/deeper

Table 8. Trends in Maka Bay fish families as indicated by preferred habitats (rank order abundances of five paired elements)

Taxon ^a	Upper Zone NISP	Middle Zone NISP	Lower Zone NISP
Inshore			
Scaridae	1	1	2
Balistidae	5	7.5	9
Holocentridae	4	4	5
<i>Acanthuridae</i>	—	7.5	9
<i>Labridae</i>	6.5	5	4
<i>Muraenidae</i>	—	—	10
Outer reef/deep water			
<i>Lethrinidae</i>	2	2	1
<i>Carangidae</i>	—	9	7
<i>Serranidae</i>	3	3	3
<i>Lutjanidae</i>	6.5	6	6

^aFamilies in italics are those which decrease one or more full ranks between the Lower and Upper Zones; those in bold are families which increase and those in roman text are temporally stable taxa.

waters were fished and an increase in inshore fishing, although the acanthurid and muraenid trends are at odds with this interpretation. In the case of the lutjanids and serranids, there could be a switch through time from deeper water to inshore species; however, given our family level identifications such a change is archaeologically invisible.

Density of fish remains

Examination of the density of fish remains is also informative (Table 9) and here we again draw on only the three zone samples (see earlier discussion), not the entire assemblage. In the Lower Zone, 203 specimens (NISP of five paired head bones) were recovered with a density of 508 NISP per m³. In the Middle Zone, the number of recovered specimens decreases to 176 and a density of 440 NISP per m³. However, by the end of the sequence, only 39 specimens were recovered and the density declined to 98 NISP per m³. The decrease in fish remains between the upper and two lower zones is unambiguous. However, the results must be interpreted with caution, as shellfish remains also decline between the Upper and two lower zones, raising the possibility that what we are seeing is a change in the intensity of faunal activities (i.e., duration of use and/or number of people) associated with the Upper Zone, or alternatively, a lateral shift in the focus of on-site activities. While such a change can not be altogether discounted, it is notable that the density of artifacts (pottery, lithics, etc.) for the three layers is fairly stable (see Wall, 1997).

Discussion

In the three Maka Bay assemblages there are indications of significant declines in two families

of piscivorous fish, increases in inshore taxa, and a decline in fish exploitation overall over a roughly 400–200-year period. However, the suggested trends are not without ambiguities, underscoring the limitations of single site analyses. Below we discuss some causal factors which may have, singly or in tandem, contributed to the apparent trends: *local habitat change* in Maka Bay; *resource depression* due to over-fishing and lack of local refugia (e.g., places with limited human contact); and/or *changing economic priorities* which might relate to any number of causal factors.

Local habitat change

Altered patterns of fish capture might stem from localized environmental change in Maka Bay proper. Some of the species which are today more commonly found in deeper water regions (e.g., lethrinids) may have been more common in the bay if marine conditions were different. Most notably the presence of a channel between Maka and Hapmafau Bays might have provided suitable habitat for, or at least increased the local occurrence of, these fish. Closure of the north–south channel and development of the sandy isthmus would have reduced water circulation within the two bays and exchange with the open sea, potentially leading to increases in both siltation and salinity. Certainly Rotumans today are concerned about the effects of siltation on local fisheries and in 1996 they artificially enlarged the main channel from Maka Bay to the open sea to improve conditions. In addition to the fish changes noted above, Veneridae, a filter-feeding shellfish which is sensitive to water turbidity, decreases through time in the Maka Bay assemblages (see Wall, 1997). However, the Maka Bay shellfish samples are quite small and the

Table 9. Density of fish remains (quantity per m³), based on 10-cm zone samples (see text for details)

	Upper Zone		Middle Zone		Lower Zone	
	NISP	MNI	NISP	MNI	NISP	MNI
Five paired head bones	98	52.5	440	153	508	143
All bones	188	75	908	203	735	178

molluscan trends from this site alone are inconclusive.

Problematically, however, the available evidence suggests that the isthmus between the two bays developed rather late in Rotuman prehistory. Wave-cut notches on both sides of the isthmus suggest the channel was open during the presumed period of initial settlement at ca. 3000 BP, based on sea level data from elsewhere in the region (e.g. Kirch, 1993; Allen, 1998; Nunn, 1998). More importantly, coring in the isthmus revealed no archaeological deposits, suggesting a very late development for this geological feature.

Assemblages from other areas of both the bay and the island at large are needed to clarify whether the Maka Bay fish and shellfish trends are local or island-wide patterns. Moreover, more detailed information on the timing of the channel closure would be useful but may be difficult to secure. While we cannot altogether discount changes in the local marine habitat as an explanation for temporal patterning in the Maka Bay fish abundances and catch composition, given the foregoing we think this might be a relatively late geomorphological development.

Resource depression

Resource depression is another potential cause for changes in the Maka Bay fish assemblages. Fish are generally considered more resilient to human predation relative to terrestrial species, but recent detailed studies (e.g. Leach & Davidson, 2001) suggest otherwise. Additionally, Rotuma has some unusual characteristics which may have rendered local fisheries particularly vulnerable to human impact, most notably the island's geographic isolation and its limited shallow water regions. While the mainland reef, the submarine bank, and Whale Bank provide a shallow water environment of ca. 186 km², it is nowhere comparable to the extensive coastlines and interlocking shallow water regions of archipelagos like Fiji, the Societies, and the like. Not only did Rotumans have few relatively shallow water areas to exploit but the local fish populations had limited refugia from which to recruit in the face of over-predation.

Some support for predation pressure comes from the 1983 Fijian Fisheries Division survey of Rotuma. They note a lower biomass for Rotuma relative to other reefs in Fiji, but also comment that it was unclear whether these patterns reflect the natural ecology of the island or recent heavy fishing pressures (Fijian Fisheries Division, 1983). They also observed a heavy reliance on imported foods, including tinned meat, suggesting that current levels of fishing may be much reduced from what they were in the prehistoric past.

Prehistoric impact on nearshore fisheries has been suggested in other Pacific areas. Leach (1997, 1986), Nichol (1989) and Leach & Davidson (2001) working in New Zealand, where nearshore environments are much more extensive, suggest that human predation can be seen in variable size frequencies of prehistoric catches, although not always in the directions expected. Anderson & McGlone (1992) report occasional range restrictions of certain species as well. The New Zealand studies point to the possibility of human impact on fisheries even in relatively plentiful environments and suggest that the Rotuma case warrants more detailed study.

Changing economic priorities

Changes in traditional Rotuman fisheries also may have been linked to those in other components of the local productive system. Allen (1992b) suggests that in the Cook Islands, the costs associated with deeper water fishing grew as agricultural production, territoriality and inter-group competition increased. At present we have little information on the prehistoric agricultural economy of Rotuma but the very small sample of pig and medium mammal remains (the latter also presumably pig but possibly dog) hint at an expanding agroecology through time. Moreover, increasing competition is well-attested in the late prehistoric archaeological record (Ladefoged, 1993a,b, 1995) and oral traditions suggest it may have begun as early as the 13th century AD (Parke, 1969).

A contraction of the Rotuman fishing range and intensification of inshore fishing

technologies would be consistent with the reallocation of time and labour to the agricultural economy. Deeper water fishing is not only more 'expensive' in terms of travel time and capital investment, but also may be more risky with respect to the certainty of catches. Moreover, piscivorous fish are at the top of the food chain where they are more likely to carry ciguatera, a health risk which Rotumans may have become increasingly aware of over time.

Regional comparisons

The composition of the three Rotuman assemblages are consistent with those from other West Polynesian areas. In particular, scarids, lethrins, and/or serranids are important on Lakeba, Tongatapu, Niuatoputapu, and Manu'a, as previously summarized by Nagaoka (1993). However, these fish families are not necessarily distinctive for the region, as they also figure prominently in central East Polynesian assemblages (e.g. Rolett, 1989; Allen, 1992a,b; Leach *et al.*, 1997). Among the larger West Polynesian assemblages is that from To'aga, Manu'a Islands analysed by Nagaoka (1993). There the 2196 specimens do not indicate much change through time, despite an occupation sequence of nearly 2500 years. In contrast, an assemblage of 2596 specimens from four sites on Lakeba hints at a pattern similar to that of Maka Bay. On Lakeba, Best (1984) records an early emphasis on lethrins at Site 197 where they comprise up to 60% of the lowest cultural layer. He notes a similar emphasis in the early, short duration site of VL21/5 on Naigani Island. However, these are sites of much greater antiquity and represent colonization occupations, in contrast to the relatively late Maka Bay assemblages.

Other comparative data comes from the broader Polynesian region, including analyses from Aitutaki, southern Cook Islands and the Marquesas Islands. On Aitutaki, Allen (1992a) documented an unambiguous pattern of declining fish consumption at four separate localities extending over a 1000-year period. Drawing on artifactual evidence, as well as the molluscan and fish fauna, Allen (1992a) argues that this

overall decline in fish consumption was paralleled by declines in angling (broadly defined as all hook technologies) and declines in the use of offshore habitats. As on Rotuma, inshore technologies (nets and stone weirs on Aitutaki) were dominant at western contact.

Similarly, in the Marquesas Islands, Rolett (1989), Dye (1990), and most recently Leach *et al.* (1997) observe temporal declines in offshore fishing in several localities. Dye argues for a decline in free-ranging and pelagic taxa (most notably carangids, scombrids, and sharks) across three Marquesan sites (but see Leach *et al.*, 1997). At Anapua as well, where sample sizes are larger, Leach *et al.* (1997) also report an early emphasis on and then decline in scombrids, followed by a decline in fishing overall. Dye (1990) ties changing fish patterns to increasing competition and usurpation of fishing rights by chiefly elite.

The accumulating evidence, from Rotuma, the southern Cook Islands, and the Marquesas—three widely separated localities in time and space—suggests that declines in offshore fishing, coupled with intensification of inshore technologies, may be a common process in the Pacific context, one intertwined to varying degrees with agricultural intensification, the growth of animal husbandry systems, and increasing competition in late prehistory. Three inter-related trends are suggested by the available fisheries evidence: (1) declines in the frequency with which outer reef environments are used; (2) intensification of inshore strategies through the use of 'cheaper' and less selective but potentially more productive mass harvesting technologies; and (3) declines in fishing overall. Do these processes underlie the patterning in the Rotuman assemblages as well? The biogeographic context of Rotuma suggests that we need to continue exploring the potential role of human predation on key deeper water taxa. Additionally, given that these findings are from a single study site with a relatively short temporal span their generality is unknown. Nevertheless, the trends in the Rotuman data are consistent with emerging regional evidence which points to the dynamic interplay of ecological, economic and social factors in effecting change in traditional Pacific fisheries.

Acknowledgements

The Rotuma Council, and the Chief and people of Itu'muta District, are thanked for their support of this project. In particular, the hospitality and friendship of the Vafo'ou family is appreciated. The assistance of Sepeti Matararaba of the Fiji Museum and Sarina Pearson in the field is much appreciated. The Maka Bay excavations were overseen by Thegn Ladefoged and funded by a grant to Ladefoged from the University of Auckland Research Committee. Jonathan Wall assisted with the field excavations and identified the faunal materials as part of his MA thesis; subsequent analyses and further interpretations were made by Allen and Ladefoged. Foss Leach and his staff at the Archaeozoology Laboratory, Te Papa, The Museum of New Zealand are gratefully acknowledged for their assistance to Wall with the faunal identifications. Alan Howard introduced us to the rich resources of his Rotuman web page. The paper has benefited from critical feedback from Virginia Butler and an anonymous reviewer. Finally, we thank Atholl Anderson and Foss Leach for organizing the 1998 *Symposium on Archaeozoology of Oceanic Islands* for the 8th International Congress of ICAZ where a preliminary version of this paper was presented.

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