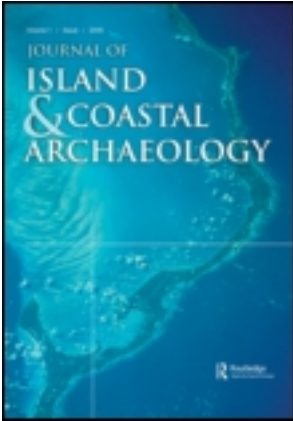


This article was downloaded by: [Australian National University]

On: 04 August 2011, At: 02:59

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



The Journal of Island and Coastal Archaeology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/uica20>

Island of Pelagic Fishermen: Temporal Changes in Prehistoric Fishing on Fais, Micronesia

Rintaro Ono^a & Michiko Intoh^b

^a Department of Marine Civilization, School of Marine Science and Technology, Tokai University, Shizuoka, Japan

^b National Museum of Ethnology, Osaka, Japan

Available online: 02 Aug 2011

To cite this article: Rintaro Ono & Michiko Intoh (2011): Island of Pelagic Fishermen: Temporal Changes in Prehistoric Fishing on Fais, Micronesia, *The Journal of Island and Coastal Archaeology*, 6:2, 255-286

To link to this article: <http://dx.doi.org/10.1080/15564894.2010.540531>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.tandfonline.com/page/terms-and-conditions>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan, sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

ARTICLES

Island of Pelagic Fishermen: Temporal Changes in Prehistoric Fishing on Fais, Micronesia

Rintaro Ono¹ and Michiko Intoh²

¹*Department of Marine Civilization, School of Marine Science and Technology, Tokai University, Shizuoka, Japan*

²*National Museum of Ethnology, Osaka, Japan*

ABSTRACT

This article presents an analysis of fish bones and prehistoric fishing on Fais in the western Caroline Islands, Micronesia. In total 18 marine fish families (26 taxa) were identified including two families of sharks (Carcharbinidae and Lamnidae). Our analysis with use of vertebrae for identification reveals that the total MNI (Minimum Number of Individuals) of inshore and offshore (outer-reef to pelagic zone) fish species is almost constant in Fais from initial settlement to early prehistoric times (AD 400 to 800) due to a drastic increase in the tuna catch. However, the number of tuna dramatically decreased after AD 1200. Although the exact reason(s) for such increase and decrease in tuna capture is uncertain, the increase could be related to changes in fishing technology, population increase, and possible climatic changes, while the drastic decrease seems directly related to accessibility of marine resources due to climatic change, particularly between AD 1200 and 1500. Based on these results, we further discuss the character of Fais fishing by comparing it with fishing on islands in other parts of Oceania.

Keywords pelagic fishing, shark fishing, temporal change, vertebrae analysis, past climate change, Fais

Received 16 June 2009; accepted 18 June 2010.

Address correspondence to Rintaro Ono, Department of Marine Civilization, School of Marine Science and Technology, Tokai University, Shizuoka, Japan. E-mail: rintaro@tokai-u.jp

INTRODUCTION

On Fais Island in Micronesia, shark and pelagic fishing are among the most important traditional fishing techniques. Even today, people on Fais engage in shark fishing as well as pelagic zone fishing aimed at species such as tuna, as part of a community subsistence strategy. The traditional method for catching sharks on Fais involves the use of a thick coconut fiber string (sennit cord) held on the surface to encircle sharks, or of large bait hooks and a thick coconut fiber line; the primary means for tuna capture is trolling with lures or hooks. Previous archaeological investigations on the island suggest that Fais has an 1,800-year period of human occupation (Intoh 1993, 1995, 1996a, 1996b, 1997); thus it is worth examining when and how peoples here began exploiting sharks and pelagic species in the past and how this may have changed over time.

Although the archaeological evidence for offshore fishing in prehistoric Oceania has increased, especially in the Mariana Islands in Micronesia (e.g., Amesbury 2008; Leach and Davidson 2006a, 2006b; Leach et al. 1988) and the Marquesas Islands in Polynesia (e.g., Davidson et al. 1999; Leach et al. 1997; Rolett 1989), the significance of offshore fish species as a protein source and its temporal change over 1,000 years of time, particularly in relation to technological, climatic, cultural, and social changes, have been only cursorily discussed in previous studies.

This is particularly true for shark fishing, which can be categorized as offshore fishing (fishing in outer-reef to pelagic zones). Consequently, elasmobranchs (sharks, skates, and rays) have played a significant role in many coastal fisheries around the world (Rick et al. 2002). Many prehistoric sites in Oceania also have produced elasmobranch bones (mainly sharks), but these bones are usually neglected in terms of detailed identification and comparison with other major bony fish species. There are three main reasons for this: a) vertebral centra, teeth, spines, and dermal denticles are the most conspicuous shark parts that are preserved in archaeological deposits; b) these bones

are hard to identify to the family or species level because of their morphological variety and the scarcity of reference collections in Oceania; and c) it is difficult to quantify these bones to produce an accurate minimum number of individuals (MNI) as a single shark often has more than 100¹ vertebrae in a variety of sizes² and with a large number of teeth (see also Rick et al. 2002:114).

To improve analysis of elasmobranch (particularly sharks) and pelagic fish bones (such as tuna), and to enhance the discussion of prehistoric pelagic and shark fishing in Oceania, we analyzed the excavated fish vertebrae and caudal peduncles to identify elasmobranch (mainly sharks) and pelagic species. Without such analysis, it is impossible or too risky to judge the significance of offshore resources in the prehistoric economies in Oceania. The broader aim of this paper is to identify fish remains recovered from excavations at the Powa site (FSPO) on Fais which has the longest known cultural sequence on the island. We also examine other excavated materials related to past marine exploitation such as fish hooks and shell tools. Second, we situate the Fais material in a regional context by examining the possible importance of pelagic fish resources among prehistoric societies in Oceania.

THE ISLAND AND ITS PEOPLE

Fais is a raised coral island in Micronesia situated at 9°46' N and 140°3' E. The nearest island is Ulithi atoll, lying about 80 km to the west (Figure 1). Politically, Fais belongs to the Yap State of the Federated States of Micronesia. The island is elongated in shape and is 2.7 km in length, about 1.1 km in width (2.8 km²), and surrounded by a narrow fringing reef except for the northeast end and the west side where the sea pounds steep cliffs.

There is neither a safe anchorage nor a good landing place for larger ships, and it is difficult even for traditional fishing canoes to go through the narrow reef channels during rough weather. No lagoon has formed, and few reef fishes are seen inside the narrow

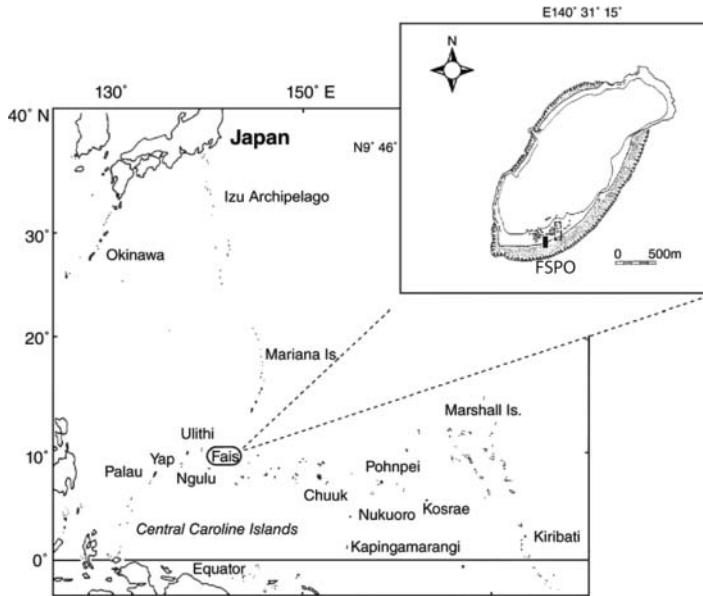


Figure 1. Location map of Fais and FSPO site.

reef around the island, while outside of the reef there is a steep drop into the deep sea. With such a coastal environment, fish are mainly caught by angling and occasionally by netting (using cast nets), from either the reef top or the reef pass. Sharks and pelagic fish are caught in the open sea and are favored for food, although sharks are typically not captured for food by the neighboring atoll peoples.

People on Fais speak a Nuclear Micronesian language considered to have dispersed from the southeastern Solomon Islands and to most parts of Micronesia except for western Micronesia, including the Marianas, Yap, the main Palauan archipelago. The original colonization of Fais is considered to have been part of this large wave of Nuclear Micronesian migration. Most of the islands in the central Caroline Islands are atolls that have limited resources and none are vulnerable to natural disasters. It is known that the inhabitants of such resource-limited environments likely maintained contacts with nearby high islands that have more abundant natural resources (Intoh 2000). Such con-

tacts were known for the central Caroline Islands. The exchange system between these atolls and Yap Island in the west is widely known as the *sawei* system (Alkire 1978; Descantes 2005; Hunter-Anderson and Zan 1996), in which the people of Fais were participants.³

ARCHAEOLOGICAL BACKGROUND

Fais was first archaeologically investigated by Intoh in 1991 and 1994 (e.g., Intoh 1993, 1995, 1996a, 1996b, 1997). Research demonstrated that Fais was continuously inhabited over the past 1,800 years. Excavated artifacts included potsherds, shell adzes, scrapers, and fishhook points; and fishhooks and cutting tools made from turtle carapace and other materials. The continuous appearance of potsherds produced in Yap indicates that there was continual cultural contact between Fais and Yap throughout the island's prehistory (Intoh and Dickinson 2002). Vertical distribution of the three types of Yapese

pottery (CST, Plain, and Laminated) indicates that pottery was constantly brought in from Yap. Small amounts of Palauan potsherds were also found. These were brought in either directly from Palau or via Yap (Intoh 2008; Intoh and Dickinson 2002).

Large numbers of faunal remains were obtained in excavations, including mollusks, crustaceans, fish, mammals (pig, dog, and rat), and birds (see Intoh and Shigehara 2003). Among them, the rats were an Asian version of *Rattus rattus*, which is distributed mainly in Southeast Asia (Intoh 1996a, 1997). This indicates that human dispersal to Fais was likely from the west rather than from the south, and contradicts aspects of the linguistic dispersal model (Bellwood 1978; Bender 1971; Blust 1984). An analysis of the excavated bird bones demonstrated that nine of the seabirds and three of the land birds no longer live on Fais (Steadman and Intoh 1994).

In 2005, the authors (headed by Intoh) conducted extensive archaeological excavations at five different sites on the island representing a total of 12 m² of excavation. Among these, the *Powa* site (FSPO) on the southern coast near the central part of the present village (Figure 1) revealed a deep cultural deposit with the oldest dates in the 2005 excavation.⁴ We excavated four 1 × 1 m units (FSPO-3, 4, 8, and 9); a total of 12 stratigraphic layers were recognized in both units, and the lowest layer reached 3.3 m depth. It should be noted that the lowest layer (Layer 12) was excavated only in FSPO 4 and 8 because of its depth and our limited time for the excavation.

Excavation was done by natural stratigraphy and all deposits were dry-screened through 3 mm (1/8 inch) mesh or recovered in situ. Cultural features such as earth ovens were photographed as were wall profiles. A very dark, packed sandy soil layer was detected at Layers 4, 6, and 9. Occasional patchy beach sand pockets were observed in some layers, but were not so persistent as to form a layer. Since no sterile layer was found between the bottom and top layers, the island seems to have been occupied fairly consistently since initial occupation.

The site produced a number of artifacts made from marine shell, coral, and bone, as well as imported potsherds (Intoh 2008; Intoh and Ono n.d.). Considerable amounts of faunal remains were also excavated, and the bones of mammals other than rats were examined by Nobuo Shigehara (Intoh 2008:132). A number of pig, dog, and porpoise remains were identified down to Layer 10, while rats and fish remains were found in abundance in all layers down to Layer 12.

Charcoal was collected from almost all layers and nine samples were submitted to Beta Analytic, Inc. for AMS dating. The results fit in good chronological order as shown in Table 1 (five dates obtained from the 1991 research are also included). Following these dates and excavated artifacts from each layer, the cultural phases at FSPO site can be ordered into the five phase I, IIA, IIB, III, and IV scheme (Table 2), which correspond to the cultural phases reconstructed by previous excavations on Fais (Intoh 2008; Intoh and Shigehara 2003).

The earliest layer (Layer 12) is dated by two samples (Beta-213060 and Beta-213061) at 1720 ± 40 BP (AD 230 to 410) and 1700 ± 40 BP (AD 240 to 420), respectively (see Intoh 2008 for details). A number of cultural remains such as *Tridacna* sp. shell adzes, shell bracelets, and shell beads were obtained, as well as a small amount of Yapese CST and Plain potsherds and faunal remains. The number of major excavated artifacts, including potsherds, pig and dog bones, shell-made materials, and others, with approximate excavation volume (m³) for each layer, is shown in Table 3. The earliest cultural phase I in Fais was characterized as AD 1 to 400 as a result of the 1991 research (Intoh 1993; Intoh and Shigehara 2003), and thus Layer 12 of the FSPO site might have been formed during Phase I, possibly the late part of the phase between AD 200 and 400 (see Table 2).

The second cultural phase is dated by one sample from Layer 11 (Beta-213062) and two samples from Layer 10 (Beta-221149 and 221150) as 1560 ± 40 BP (AD 410–600), 1550 ± 40 BP (AD 420–610), and 1510 ± 40 BP (AD 440–640), respectively. These dates overlap and can be combined into the same

Table 1. Radiocarbon results.*

Lab. #	Square	Layer	Depth	Conventional age (BP)	Calibrated age**	$\delta^{13}C$
Wk-3567	FSPO-2	3	46–60 cm	700 ± 60	AD 1264–1389	–25.4
NZ7886	FSPO-2	6	130 cm	739 ± 120	AD 1037–1409	–26.6
Beta-213064	FSPO-3	6	110 cm	770 ± 40	AD 1200–1290	–29
Beta-79259	FSPO-2	7	140 cm	990 ± 140	AD 895–1205	–24.4
Beta-213063	FSPO-3	8	140 cm	1360 ± 40	AD 630–710	–26.3
NZA2137	FSPO-2	9	180 cm	1376 ± 62	AD 553–777	–26
Beta-221149	FSPO-3	10	190 cm	1550 ± 40	AD 420–610	–24.8
Beta-221150	FSPO-8	10	180 cm	1510 ± 40	AD 440–640	–26.5
Beta-237516	FSPO-8	11	220 cm	1540 ± 40	AD 420–610	–26.2
Beta-213062	FSPO-3	11	230 cm	1560 ± 40	AD 410–600	–26.2
NUTA2347	FSPO-2	12	250–60 cm	1433 ± 109	AD 468–687	n.a.
Beta-213060	FSPO-4	12	280 cm	1720 ± 40	AD 230–410	–26.1
Beta-213061	FSPO-4	12	260 cm	1700 ± 40	AD 240–420	–26.8
Beta-237515	FSPO-9	12	270 cm	1650 ± 40	AD 260–280	–25.5

*All the dated sample was charcoal.

**2 sigma Calib. age at 95% probability (Stuiver et al. 1998).

cultural phase (IIA), possibly between AD 400 and 600. This period is characterized by a large number of Yapese CST potsherds and some Plain potsherds. A number of shell artifacts such as *Tridacna* sp. shell adzes, shell bracelets, shell beads, etc., were obtained (see Table 3). Considerable amounts of faunal remains were also found. The significant point here is that pig and dog bones appear early in Layer 10.

The date for Layer 8 was 1360 ± 40 BP (AD 630 to 710). The number of Plain potsherds increased from Layer 9 to

Layer 8 and became dominant in Layer 7. The number of CST potsherds was almost equal in these layers, while the use of turtle carapace for blade tools and single fishhooks increased suddenly in these layers (see Table 3). Although Layer 7 has a ¹⁴C date between AD 895 and 1205 from the 1991 excavation (FSPO2), the excavated materials from this layer seem similar to those from Layers 8 and 9, and thus we recognized these three layers as Phase IIB, possibly dated between AD 600 and 800.

Table 2. Cultural phases in Fais and FSPO.

Cultural Phase	Age	FSPO	FSFA1*	FSFA2*
IV	AD 1400–historic (AD1200–1400)	Layers 1–4 Layers 5–6	Layer 1	Layer 1
III	AD 800–1400		Layers 2–3	Layers 2–3
IIB	AD 600–800	Layers 7–9		
IIA	AD 400–600 (AD 200–400)	Layers 10–11 Layer 12	Layer 4	Layer 4
I	AD 1–400			Layers 5–6

*Excavated in 1991 (Intoh and Shigehara 2003).

Table 3. Number of major artifacts excavated from FSPO (3, 4, 8, and 9).

Phase	IV				III			IIB		IIA		I		Total
	1	2	3	4	5	6	7	8	9	10	11	12		
Excavation volume (m³)*	0.4	0.3	2	1	1	1	1	0.3	1	2	0.7	1.6	12.3	
Potsherd	8	10	6	13	3	14	84	72	53	40	114	2	419	
Laminated potsherd	++	++	++	++	+	+	-	-	-	-	-	-	-	
Plain potsherd	-	-	-	-	+	+	++	++	+	+	+	-	-	
CST potsherd	-	-	-	-	+	+	+	+	++	++	++	+	-	
Pig**	7	-	-	-	-	2	4	1	4	2	-	-	20	
Dog**	-	2	1	2	-	1	5	6	10	6	-	-	33	
Shell ornament	1	-	-	-	2	9	1	2	3	1	7	8	34	
Shell adze	-	-	1	-	-	3	5	6	-	2	1	3	21	
Shell scraper	1	-	-	1	-	3	-	-	-	-	-	-	5	
Single fishhook	-	-	-	-	-	-	-	3	2	-	-	-	5	
Trolling lure	-	-	-	1	1	-	-	-	-	-	-	-	2	
Worked bone	-	-	-	1	-	4	8	9	6	2	2	-	32	
Perforated teeth	-	-	-	-	-	-	3	2	1	-	-	-	6	
Worked shell	-	-	-	1	-	-	1	-	3	-	2	-	7	
Worked sea urchin	-	1	-	-	-	1	1	-	1	-	-	-	4	
Worked coral	-	-	-	-	-	-	2	2	-	-	-	-	4	

*Volume of excavation of each layer is approximate based on our field notes.

**NISP value.

Layer 6 was dated to 770 ± 40 BP (AD 1200 to 1290). Beginning with this layer, the number of potsherds decreased considerably. Laminated potsherds, the latest Yapese pottery, first appeared in Layer 6 and were continuously found through to Layer 1, while Plain and CST potsherds disappeared from Layer 4 (see Intoh 2008:figure 5). The variation of material culture did not change much except that *Cassia* sp. shell scrapers first appear in this layer. The previous excavations indicate that the cultural phase III in Fais is possibly between AD 800 and 1400 (Intoh and Shigehara 2003), and Layer 6 and 5 at FSPO site can be identified as belonging to the later part of Phase III, around AD 1200 to 1400.

Although no ^{14}C dates were acquired from Layer 5 and above in our 2005 excavation, the absence of Plain and CST potsherds in Layer 4 indicates that these upper layers (Layer 4 to 1) possibly correspond to Phase IV, which dates to post AD 1400, based on the previous excavations in Fais (Intoh and Shigehara 2003). In any case, it is clear that the upper layers (Layer 6 to 1) at FSPO were formed later around AD 1200.

FISH BONE ANALYSIS

After excavation, all faunal remains and artifacts were borrowed under a permit issued by the Historic Preservation Office (HPO) in Yap and transported to the National Museum of Ethnology at Osaka, Japan, for further analysis. The methods of fish bone analysis followed the technique developed by Ono and others for the treatment of tropical fish remains from Island Southeast Asia (e.g., Ono 2003, 2004), Oceania (e.g., Leach 1986; Leach and Davidson 1977; Vogel 2005), and Okinawa (e.g., Toizumi 2007). In our study, fish bones were identified and counted by calculating both NISP (Number of Identified Specimens) and MNI in each layer/unit (FSPO 3, 4, 8, and 9), and these counts were integrated into a total NISP and MNI in a phase/site measure as shown in Table 4. It should be noted that we did not re-count MNI when we integrated them into both phase and site measures.

Cranial elements, special elements, vertebrae, and teeth were used for identification. The cranial elements used include the maxilla, premaxilla, dentary, articular, quadrate, pharyngeal clusters, opercle, preopercle, hyomandibular, palatine, cleithrum, supra-cleithrum, post-temporal, scapula, ephial, and ceratohyal; special elements included the erectile spines of triggerfish (Balistidae) and unicornfish (Acanthuridae), spines of porcupinefish (Diodontidae), scute of trevally (Carangidae) and unicornfish (Acanthuridae), and caudal peduncle of tuna (Scombridae). Teeth were also used only for identification of sharks, triggerfish, and one species of Lethrinidae (*Monotaxis granoculis*).

All fish bones from an excavation unit and a layer were designated to be a discrete assemblage. Following methods outlined by Leach (1986), each assemblage was sorted into identifiable and unidentifiable remains, and all bones were re-bagged, with identifiable fragments sorted anatomically and re-bagged. Taking each part of the anatomy in turn, bones were sorted into species, genera, and families, and identified using comparative collections.

The MNI and number of identified specimens (NISP) were calculated using methods described by Chaplin (1971), although size mismatches were also taken into account (e.g., Ono 2003, 2004). The exception is shark vertebrae, which have a wide size range in an individual specimen (e.g., Kaneko and Saito 1980; Springer and Garrick 1964), so that the MNI of each shark assemblage is counted as "1" in each test unit; hence the maximum number of each shark taxon MNI in each layer can only be "4" when we integrate the four units (see Appendix 2).

GENERAL RESULTS OF FISH BONE ANALYSIS

A total of 13,277 fish bones were counted from the FSPO sites (about 14.3 m^3) by our 2005 excavation. The distribution of identified anatomical elements (31 components) is indicated in Figure 2. The major anatomical elements used for identification were

Table 4. MNI and NISP of each fish taxon by phase level (% in MNI).

Cultural phase age	Genus/species	IV		III		IIB		IIA		I		Total	
		AD 1400- MNI (NISP)	%	AD 1200-1400 MNI (NISP)	%	AD 600-800 MNI (NISP)	%	AD 400-600 MNI (NISP)	%	AD 200-400 MNI (NISP)	%	MNI (NISP)	%
Inshore fish													
Serranidae		36 (104)	20.9	27 (70)	25.2	49 (128)	17.6	35 (132)	21.6	11 (36)	25.5	158 (470)	21.2
Scaridae		16 (27)	9.5	7 (10)	6.9	23 (48)	8.2	13 (18)	8.3	3 (3)	6.9	62 (106)	8.3
Balistidae		12 (14)	7.1	6 (7)	6	18 (20)	6.4	17 (31)	10.4	8 (15)	18.6	61 (87)	8.1
Lutjanidae		13 (21)	7.7	5 (9)	4.9	16 (24)	5.7	10 (22)	6.4	3 (5)	6.9	47 (81)	6.3
Acanthuridae		13 (26)	7.7	6 (9)	6	14 (15)	5	9 (12)	5.8	3 (3)	6.9	45 (67)	6
Lethrinidae		11 (14)	6.5	11 (21)	10.8	11 (17)	3.9	6 (21)	3.8	2 (3)	4.6	44 (80)	5.9
	<i>Monotaxis</i> sp.	1 (1)		1 (1)		1 (1)		1 (1)		0			
Diodontidae		6 (11)	3.5	3 (7)	2.8	10 (30)	3.5	6 (7)	3.8	0		25 (55)	3.3
Labridae		6 (6)	3.5	1 (1)	0.9	7 (8)	2.5	2 (4)	1.2	1 (1)	2.3	17 (20)	2.2
Haemulidae		0		2 (2)		2 (2)		0		0		4 (4)	0.5
Siganidae		2 (3)		0		0		2 (3)	1.2	0		4 (6)	0.5
Muraenidae		1 (1)		2 (2)		3 (6)	1	0		0		6 (9)	0.8
Holocentridae		0		0		1 (1)		3 (3)	1.9	1 (2)	2.3	5 (5)	0.6
Ostraciidae		1 (1)		0		1 (1)		0		0		2 (2)	0.2
Sub-total		118 (229)	68.6	71 (139)	66.3	156 (302)	56.1	104 (254)	64	32 (70)	74.4	480 (992)	64.5
Offshore fish													
Carcharhinidae		28 (56)	16.2	18 (75)	16.8	39 (260)	14	23 (73)	14.1	7 (18)	16.2	115 (482)	15
Type A	<i>C. plumbeus</i>	8 (16)		5 (41)		12 (105)		7 (30)		3 (8)		35 (200)	
Type B	<i>C. falciro</i>	5 (9)		3 (13)		12 (61)		7 (17)		2 (6)		29 (106)	
Type C	<i>C. galapag</i>	6 (20)		5 (12)		10 (55)		5 (16)		2 (4)		28 (107)	
Type D	Prionace	8 (11)		3 (9)		5 (39)		4 (10)		0		20 (69)	
Type E	Galeocerdo	1 (4)		0		0		0		0		1 (4)	
Unknown A		12 (58)		7 (47)		12 (241)		8 (69)		2 (17)		41 (432)	5.5
Unknown B		0		1 (1)		2 (2)		0		1 (1)		4 (4)	0.5
Unknown C		0		0		1 (1)		1 (2)		0		2 (3)	0.25
Lamnidae		0		0		2 (2)		0		0		2 (2)	0.25
Tooth (NISP)		31		40		165		39		21		296	
Fragments (NISP)		7		0		20		7		0		34	
Shark-total		40 (118)	23.2	24 (123)	22.4	56 (506)	20.1	32 (144)	20	10 (36)	23.2	162 (1257)	21.5
Scombridae		8 (22)	4.6	10 (30)	9.3	61 (802)	21.9	20 (186)	12.3	1 (1)	2.3	100 (1041)	11.1
Carangidae		6 (7)	3.5	2 (2)	1.9	4 (4)	1.4	5 (7)	3.2	0		17 (20)	2.2
Sphyraenidae		0		0		1 (1)		1 (1)	0.6	0		2 (2)	0.2
Sub-total (fish+shark)		54 (147)	31.3	36 (155)	33.6	122 (1313)	43.8	58 (338)	36	11 (37)	25.5	281 (2320)	35.4
Total		172 (376)		107 (294)		278 (1615)		162 (592)		43 (107)		761 (2982*)	

* Excluding number of shark tooth and fragments.

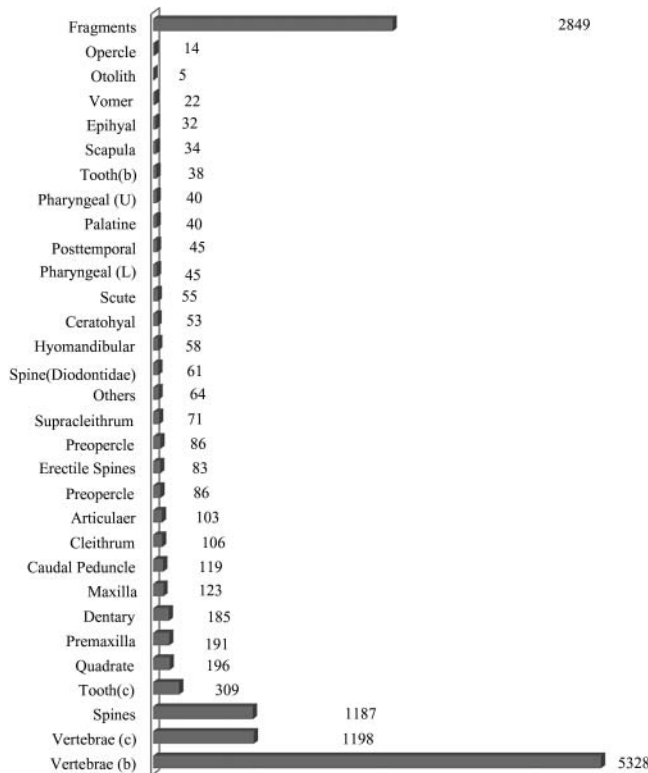


Figure 2. Number of identified elements extracted from FSPO in 2005. (Note: (b) = fish, (c) = cartilage fish, (U) = upper clusters, (L) = Lower clusters.)

a) vertebrae (both bony and elasmobranch fish), b) quadrate, c) premaxilla, d) dentary, e) maxilla, f) cleithrum, and g) articular. As shown in Figure 2, the number of vertebrae (both bony fish and elasmobranchs) far exceed the number of other cranial elements at FSPO, and the six bony fish taxa (Serranidae, Scaridae, Scombridae, Balistidae, Muraenidae, and Carangidae) were identified by use of excavated vertebrae, while nine taxa, including three unknown species, were classified for elasmobranchs.

Table 4 shows the MNI and NISP of FSPO fish remains by cultural phase. The detailed results of both NISP and MNI by stratigraphic layer are described in Tables 5 and 6. The total number of identified fish remains in family levels added up to a MNI of 761 and an NISP of 2982. Twenty-six discrete taxa were

identified, including 16 families and one species (*Monotaxis granoculis*). The MNI of Serranidae (groupers) and Elasmobranch (mostly sharks) are highest, as both occupied about 15 to 20% of total MNI. The second largest MNI belong to Scombridae (tuna) and Scaridae (parrotfish), as the former made up about 11% of the total MNI, while the latter occupied about 8%. Other major fish families in FSPO are Balistidae, Lethrinidae, Lutjanidae, Acanthuridae, Carangidae, and Diodontidae.

Composite chi-square values and adjusted residuals for adjacent FSPO strata are provided in Table 7. In this analysis, all χ^2 significance values are based on monte carlo significance tests with 10,000 sample tables and the p values for the overall chi squares running the monte carlo simulations

Table 5. NISP of identified fish bones from FSPO (layer).

Inshore taxa	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total
Serranidae	16	36	5	47	25	45	43	47	38	28	104	36	470
Scaridae	3	8	2	14	4	6	8	14	26	4	14	3	106
Balistidae	3	4	0	7	2	5	6	5	9	6	25	15	87
Lutjanidae	4	3	5	9	0	9	5	10	9	4	18	5	81
Lethrinidae	6	1	3	4	10	11	10	3	4	2	19	3	76
<i>Monotaxis</i> sp.	0	0	0	1	1	0	0	0	1	1	0	0	4
Acanthuridae	4	7	0	15	1	8	2	2	11	1	11	5	67
Diodontidae	0	3	1	7	1	6	10	8	12	3	4	0	55
Labridae	2	1	0	3	1	0	4	2	2	0	4	1	20
Haemulidae	0	0	0	0	0	2	0	2	0	0	0	0	4
Siganidae	2	0	1	0	0	0	0	0	0	0	3	0	6
Muraenidae	0	0	0	1	0	2	5	0	1	0	0	0	9
Holocentridae	0	0	0	0	0	0	0	0	1	0	3	1	5
Ostraciidae	0	1	0	0	0	0	1	0	0	0	0	0	2
Subtotal	40	64	17	108	45	94	94	93	114	49	205	69	992
Pelagic-out reef													
Carcharhinidae A	10	2	2	2	1	40	45	24	36	8	22	8	200
Carcharhinidae B	3	4	0	2	0	13	25	14	22	5	12	6	106
Carcharhinidae C	7	5	2	6	4	8	20	12	23	7	9	4	107
Carcharhinidae D	3	4	1	3	1	8	17	8	14	5	5	0	69
Carcharhinidae E	0	0	0	4	0	0	0	0	0	0	0	0	4
Unknown A	31	17	4	6	7	40	80	52	109	29	40	17	432
Unknown B	0	0	0	0	0	1	2	0	0	0	0	1	4
Unknown C	0	0	0	0	0	0	0	0	1	0	2	0	3
Lamnidae	0	0	0	0	0	0	0	0	2	0	0	0	2
Fragment/others	0	5	0	2	0	0	8	2	10	6	1	0	34
Tooth	9	10	0	12	10	30	64	46	55	23	16	21	296
Subtotal	63	47	9	37	23	140	261	158	272	83	107	57	1257
Scombridae	0	1	1	20	6	24	93	233	476	157	29	1	1041
Carangidae	2	3	0	2	0	2	3	0	1	0	7	0	20
Sphyraenidae	0	0	0	0	0	0	0	0	1	1	0	0	2
Subtotal	2	4	1	22	6	26	96	233	478	158	36	1	1063
Total	105	115	26	150	69	240	370	271	432	145	322	127	3312

in PASW were all significant at $p = .000$. The residuals⁵ are to be read as standard normal deviates (Everitt 1977); the signs of

those residuals refer to the stratum to the left of the residuals column (e.g., Grayson and Delepech 2003). For example, the increase

Table 6. MNI of identified fish bones from FSPO (layer).

Taxa	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	Total
Serranidae	7	12	3	14	13	14	13	19	17	13	22	11	158
Scaridae	2	5	2	7	3	4	5	6	12	2	11	3	62
Balistidae	2	4	0	6	1	5	6	5	7	5	12	8	61
Lethrinidae	3	1	2	5	6	5	6	2	3	1	5	2	41
<i>Monotaxis</i> sp.	0	0	0	0	1	0	0	0	1	1	0	0	3
Acanthuridae	3	4	0	6	1	5	2	2	10	1	8	3	45
Lutjanidae	2	3	3	5	0	5	4	7	5	3	7	3	47
Diodontidae	0	1	1	4	1	2	3	3	4	3	3	0	25
Labridae	2	1	0	3	1	0	3	2	2	0	2	1	17
Haemulidae	0	0	0	0	0	2	1	1	0	0	0	0	4
Siganidae	1	0	1	0	0	0	0	0	0	0	2	0	4
Muraenidae	0	0	0	1	0	2	2	0	1	0	0	0	6
Holocentridae	0	0	0	0	0	0	0	0	1	0	3	1	5
Ostraciidae	0	1	0	0	0	0	1	0	0	0	0	0	2
Subtotal	22	32	12	51	27	44	46	47	63	29	75	32	480
Carcharhinidae A	2	2	2	2	1	4	4	4	4	4	3	3	35
Carcharhinidae B	1	2	0	2	0	3	4	4	4	3	4	2	29
Carcharhinidae C	2	2	1	1	3	2	3	3	4	3	2	2	28
Carcharhinidae D	1	3	1	3	1	2	2	1	2	2	2	0	20
Carcharhinidae E	0	0	0	1	0	0	0	0	0	0	0	0	1
Unknown A	4	4	2	2	3	4	4	4	4	4	4	2	41
Unknown B	0	0	0	0	0	1	1	0	1	0	0	1	4
Unknown C	0	0	0	0	0	0	0	0	1	0	1	0	2
Lamnidae	0	0	0	0	0	0	0	0	2	0	0	0	2
Subtotal	10	13	6	11	8	16	18	16	22	16	16	10	162
Scombridae	0	1	1	6	4	6	12	20	29	13	7	1	100
Carangidae	1	3	0	2	0	2	3	0	1	0	5	0	17
Sphyraenidae	0	0	0	0	0	0	0	0	1	1	0	0	2
Subtotal	1	4	1	8	4	8	15	20	31	14	12	1	119
Total	33	49	18	67	36	65	78	82	118	56	99	43	761

in abundance of Scombrids from Phase I to Phase IIA is associated with an adjusted residual of +6.4937 ($p < .001$). The corresponding value in the other direction can be obtained by changing the sign of the residual (-6.4937 for the dramatic decrease

in Scombrids abundance from Phase IIA to Phase D). The statistics provided in Table 7 also show that the abundances of fish taxa in Phase I differ significantly from those in Phase IIA ($\chi^2 = 57.12$, $p < .001$), with this relationship driven by the changing

Table 7. NISP by stratigraphic unit and taxon: Adjusted residuals (AR) and composite X2 values.*

Taxa	IV (AR)	III (AR)	IIIB (AR)	IIA (AR)	I (AR)	I			
Serranidae	104	1.1279 ($p = .2594$)	70	8.2112 ($p < .0000$)	128	-9.2729 ($p < .0000$)	132	-2.6470 ($p = .0081$)	36
Caracharhinidae	60	-3.0591 ($p = .0022$)	75	3.8968 ($p = .0001$)	260	2.1963 ($p = .0281$)	73	-1.3487 ($p = .1774$)	18
Elasmobranchii (non-Cara)	58	-0.3171 ($p = .7512$)	48	0.4739 ($p = .6356$)	246	1.9273 ($p = .0539$)	71	-1.4571 ($p = .1451$)	18
Scombridae	22	-2.0898 ($p = .0366$)	30	-12.5572 ($p < .0000$)	802	7.6468 ($p < .0000$)	186	6.4937 ($p < .0000$)	1
Scaridae	27	2.1254 ($p = .0336$)	10	0.3926 ($p = .6946$)	48	-0.0813 ($p = .9352$)	18	0.1013 ($p = .9193$)	3
Balistidae	14	0.9896 ($p = .3224$)	7	1.5245 ($p = .1274$)	20	-5.5558 ($p < .0000$)	31	-3.4420 ($p = .0006$)	15
Lutjanidae	21	1.5676 ($p = .117$)	9	1.9043 ($p = .0569$)	24	-3.2469 ($p = .0012$)	22	-0.5117 ($p = .6089$)	5
Acanthuridae	26	2.2246 ($p = .0261$)	9	3.0167 ($p = .0026$)	15	-2.0776 ($p = .0377$)	12	-0.5402 ($p = .5891$)	3
Lethrinidae	15	-1.9646 ($p = .0495$)	22	7.0094 ($p < .0000$)	18	-4.0569 ($p < .0000$)	22	0.4363 ($p = .6626$)	3
Diodontidae	11	0.4326 ($p = .6653$)	7	0.5972 ($p = .5504$)	30	1.0960 ($p = .2731$)	7	1.1199 ($p = .2628$)	0
Labridae	6	1.5862 ($p = .1127$)	1	-0.3580 ($p = .7203$)	8	-0.5093 ($p = .6105$)	4	-0.3096 ($p = .7569$)	1
Haemulidae	0	-1.6017 ($p = .1092$)	2	1.9182 ($p = .0551$)	2	0.8569 ($p = .3915$)	0	—	0
Siganidae	3	1.5350 (0.1248)	0	—	0	-2.8619 ($p = .0042$)	3	0.7310 ($p = .4648$)	0
Muraenidae	1	-0.7971 ($p = .4254$)	2	0.7530 ($p = .4515$)	6	1.4855 ($p = .1374$)	0	—	0
Holocentridae	0	—	0	-0.4269 ($p = .6695$)	1	-2.1759 ($p = .0296$)	3	-1.5644 ($p = .1177$)	2
Ostraciidae	1	0.8849 ($p = .3762$)	0	-0.4269 ($p = .6695$)	1	0.6058 ($p = .5446$)	0	—	0
Carangidae	7	1.3182 ($p = .1874$)	2	1.2180 ($p = .2232$)	4	-2.7614 ($p = .0058$)	7	1.1199 ($p = .2628$)	0
Sphyrnidae	0	—	0	-0.4269 ($p = .6695$)	1	-0.7396 ($p = .4595$)	1	0.4214 ($p = .6755$)	0
Total	376		294		1614		592		105
χ^2		39.312 ($p = .000$)		231.89 ($p = .000$)		201.881 ($p = .000$)		57.12 ($p = .000$)	

* All χ^2 significance values are based on monte carlo significance tests with 10000 sample tables.

abundance of Scombrids, which increases significantly from Phase I to Phase IIA, and of Serranids, Balistids, and Lethrinids which decrease significantly. Likewise, Phase IV differs significantly from Phase III ($\chi^2 = 39.312, p < .001$), with this difference driven by a continual decrease in Scombrids and Carcharhinids coupled with a significant increase in Scarids and Acanthurids. From this perspective, there is a very significant change in the relative abundances of fish taxa across the phases at FSPO.

In terms of NISP count, the numbers of elasmobranchs and tuna far exceed those of other bony fish taxa (see Table 4). This may be caused by the larger number of excavated vertebrae identified from these species, and we should note that tuna were mainly identified by use of vertebrae and caudal peduncles since the number of these elements was large, while the number of cranial bones for this family was very limited (see Table 8) and far smaller than that of other bony fish species (e.g., Serranidae, Scaridae, Lutjanidae, and Lethrinidae). On the other hand, the total number of vertebrae identified to other bony fish taxa was extremely small, and these taxa were mainly identified by their cranial bones (e.g., premaxilla, maxilla, quadrate, and dentary).

The diameter of tuna vertebrae ranges from 8 to 22 mm, and the morphological characters for some vertebrae and caudal peduncles are similar to those of *Katsuwonis pelamis* (skipjack) and *Thunnus albacares* (yellowfin). Although it is not so simple to reconstruct and discuss the actual size and meat weight from bone size because of the possible effect of individual variation, sexual dimorphism, and allometric scaling (e.g., Reitz and Wing 2008; Seymour 2004), the size range of tuna vertebrae excavated from FSPO indicates that most of these specimens were possibly middle- to larger-sized tuna at least 40 cm in total length, when we tentatively compare them with the data for vertebra size, actual length, and weight based on the reference collection (see Table 9).

Our study confirms that vertebrae are also useful for the identification of elasmobranchs, and we classified them into nine taxa including at least two shark families,

Carcharhinidae and Lamnidae, based on the vertebrae morphology. Among these two families, Carcharhinidae can be classified further into five taxa based on vertebrae morphology. With the limited number and variety of references for the shark bones in the authors' collection, it is difficult to assign these five taxa to a species, though they possibly belong to *Carcharhinus plumbeus* and *Carcharhinus longimanus* (Type A), *Carcharhinus falcif* (Type B), and *Carcharhinus galapag* (Type C), genus *Prionace* (Type D), or genus *Galeocerdo* (Type E).⁶

Besides Carcharhinidae, one type of vertebra was identified as Lamnidae, though three different taxa could not be identified even to family level mainly due to the lack of reference collections and were simply classified as Unknown Type A, B, and C. These three unknown types, however, are morphologically distinct from other identified taxa, and thus we counted both MNI and NISP of these taxa as shown in Table 4.

Table 10 shows the total number of excavated shark vertebrae sorted by diameter size range. As shown in Table 10, most of the Carcharhinidae and Lamnidae vertebrae were over 20 cm in diameter. Our tentative comparison with our reference collection indicates that *Carcharhinus plumbeus* or *Carcharhinus longimanus* (Carcharhinidae Type A) specimen (whose monospondylous precaudal vertebra is sized around 20 mm) ranged from 190 to 200 cm in total length and about 40 to 60 kg in total weight (see Table 11). On the other hand, *Carcharhinus falcif* and *Carcharhinus galapag* specimens (Carcharhinidae Type B and C) whose vertebra is over 20 mm were possibly over 200 cm in total length and over 80 kg in total weight. Similarly, a *Prionace glauca* specimen (Carcharhinidae Type D) whose monospondylous precaudal vertebra is over 20 mm, would have been over 200 cm in total length and over 100 kg in total weight (Table 11).⁷

These limited data tentatively indicate that most of the Carcharhinidae and Lamnidae specimens exploited at FSPO were of middle to larger size, possibly around 200 cm

Table 8. Number of excavated tuna bones from FSPO (3, 4, 8, and 9).

Phase	IV				III		IIB			IIA		I	Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Vertebra	0	0	1	17	5	22	81	214	441	144	26	0	951
Caudal peduncle	0	1	0	3	1	2	11	17	29	10	1	1	76
Scapula	0	0	0	0	0	0	1	0	2	0	1	0	4
Dentary	0	0	0	0	0	0	0	0	2	2	0	0	4
Premaxilla	0	0	0	0	0	0	0	1	1	0	0	0	2
Maxilla	0	0	0	0	0	0	0	1	1	0	0	0	2
Epihyal	0	0	0	0	0	0	0	0	0	1	1	0	2
NISP (Layer)	0	1	1	20	6	24	93	233	476	157	29	1	1041
MNI (Layer)	0	1	1	6	4	6	12	20	29	13	7	1	100
MNI (Phase)	8			10			61			20		1	100

in total length. On the other hand, most of the cranial bones and vertebrae assigned to other inshore fish taxa, particularly groupers, are relatively small and possibly belonged to small fish (about 20 to 30 cm in total length), and thus sharks may have had a very important role as a source of meat and protein in prehistoric Fais along with tuna. Similar to tuna vertebrae, however, it is not so simple to reconstruct the actual size and meat weight from bone size, and further study with a larger reference collection and various assumptions is required to discuss the total meat weight of each taxon consumed at the site.

TEMPORAL CHANGES IN MARINE EXPLOITATION

The results of excavation and fish bone analysis clearly indicate that fishing and marine exploitation was one of the most important subsistence activities in the past in Fais. The results also indicate that both offshore species—mainly sharks (especially *Carcharhinidae*) and tuna—and inshore species such as groupers and parrotfish were heavily exploited in prehistoric Fais. Among these fish, the exploitation of sharks and groupers began in Phase I at FSPO.

Figure 3 shows the temporal distribution (by phase) of groupers, sharks, and tuna at FSPO. As the figure indicates, the MNI of groupers and sharks gradually increases from Phase I (AD 200 to 400) and is highest during Phase IIB (AD 600 to 800), then slightly decreases in the later phases (III and IV) which appear to date to after AD 1200 at FSPO. As shown in Table 3, each excavation volume of Phase IIA (2.7 m³) and IIB (3.3 m³) is not much larger than that of later phases (e.g., Phase III for 3 m³, and Phase IV for 3.7 m³). Although the total excavation volume of Phase I (Layer 12) is only 1.6 m³ and is far smaller than that of Phase IIA and IIB, this is mainly because in Layer 12, only two units (2 m²) were excavated; hence the volume could be 3.2 m³ if all four units had been excavated as was done in the upper layers. Even if we assume an exact volume that is twice the size and simply double the number of excavated fish bones from Layer 12, however, the number (e.g., MNI of groupers would be “22”) is still much smaller than that of Phase IIA and B (see Figure 3). Thus, the dramatic increase in the number of fish bones (including certain taxa noted in Figure 3 and Table 7) has no relationship to the excavation volume.

Although the ratio of groupers and sharks within the total MNI of identified

Table 9. Relationship between vertebra size and actual size for Scombridae.

ID #	Species	Vertebra size range	Total length	Total weight	Sample location
Ono B0011	<i>Katsuwonus pelamis</i>	5-6 mm	39 cm	700 g	Australia
ANH F0109	<i>Katsuwonus pelamis</i>	9-10 mm	46 cm	2,000 g	Solomon
ONO B0012	<i>Katsuwonus pelamis</i>	10-11 mm	60 cm	3,000 g	Tokelau
ANH F0104	<i>Thunnus albacares</i>	10-11 mm	65 cm	4,000 g	Solomon
ANH F0105	<i>Thunnus albacares</i>	14-15 mm	65 cm	4,000 g	Solomon
ONO B0010	<i>Thunnus albacares</i>	14-15 mm	70 cm	5,000 g	Tokelau
ANH F0114	<i>Gymnosarda nuda</i>	10-11 mm	55 cm	2,200 g	Solomon
ANH F0104	<i>Gymnosarda nuda</i>	14-15 mm	73 cm	5,750 g	Solomon
ANH F0181	<i>Scomberomorus commersoni</i>	15-17 mm	95 cm	9,000 g	Solomon
ANH F0191	<i>Scomberomorus commersoni</i>	16-18 mm	1,050 cm	13,000 g	Solomon
ANH F0159	<i>Rastneltiger kanagurta</i>	7-8 mm	32 cm	unknown	Solomon

Table 10. Size range of excavated shark vertebrae (FSPO 3, 4, 8, and 9).

Taxa	Group	Phase Size/layer	IV				III				IIA				I				NISP	%
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Carcharhinidae A	<i>C. plumbeus</i>	20 mm >	3	1	2	1	1	15	28	18	13	4	21	4	111	56.6				
		15–19 mm	3	2	0	1	0	11	9	5	15	3	2	2	53	27				
		10–14 mm	1	0	0	1	0	7	5	1	3	1	1	2	22	11.2				
		10 mm <	3					3					4		10	5.1				
Carcharhinidae B	<i>C. fasci</i>	20 mm >	1	1	1	1	0	6	18	7	17	3	4	4	63	52.9				
		15–19 mm	1				1	7	7	3	2	2	1	2	26	21.8				
		10–14 mm	1	4				1	8	3	2	1			20	16.8				
		10 mm <						3	1			2	2	2	10	8.4				
Carcharhinidae C	<i>C. galapag</i>	20 mm >	3	2	3	3	3	6	10	11	14	4	6	1	63	64.2				
		15–19 mm	3	5	2	2	3	3	2	2		2	2	1	20	20.4				
		10–14 mm	1	2	2	2	2	2	1	1	1	1	3		12	12.2				
		10 mm <						1	1						3	3				
Carcharhinidae D	Prionace	20 mm >			2			12		5					19	70.3				
		18 mm			2					1	2				5	18.5				
		10 mm <											3		3	11.1				
		20 mm >	1		1			2							4	66.6				
Carcharhinidae E	Galeocerdo	20 mm >				1									2	35.3				
		18 mm						2	13	13	4	16	3	6	3	60	13.3			
		20 mm >					2	13	13	4	16	3	6	3	60	13.3				
		15–19 mm	7	3	1	4	3	10	34	21	30	6	13	4	136	30.1				
Unknown A		10–14 mm	10	5	2	3	2	11	29	20	40	10	10	5	147	32.5				
		10 mm <	17	6	1	1	2	10	9	13	19	13	12	5	108	23.9				
		16–19 mm						2			4				6	75				
		13–15 mm					1							1	2	25				
Unknown C		20 mm >											2		2	40				
		18 mm											1		3	60				
		28 mm											1		1	100				
		NISP (Layer)	53	31	9	24	14	111	189	109	187	54	92	36	911					
MNI (Layer)	10	13	6	11	8	16	18	16	22	16	16	10	162							
MNI (Phase)			40			24		56		32	10	162								

Table 11. Size relation between monospondyloous precaudal vertebra, total length, and weight.

Family	Genus	ID #	Species	Vertebra size	Total length	Total weight
Lamnidae	Isurus	ONOE0101	<i>I. oxyrinchus</i>	34 mm	243.9 cm	109 kg
Carcharhinidae	Carcharhinus	ONOE0102	<i>C. plumbeus</i>	19 mm	192 cm	43.2 kg
	Carcharhinus	ONOE0103	<i>C. longimanus</i>	22 mm	205 cm	58.5 kg
	Carcharhinus	ONOE0104	<i>C. falcif</i>	25 mm	226 cm	95.9 kg
	Carcharhinus	ONOE0105	<i>C. galapag</i>	25 mm	225 cm	129.8 kg
	Prionace	ONOE0106	<i>P. glauca</i>	22 mm	272 cm	117 kg
Sphyrnidae	Galeocerdo	ONOE0107	<i>G. currier</i>	24 mm	258 cm	99.7 kg
	Sphyrna	ONOE0108	<i>S. lewini</i>	27 mm	226.5 cm	60 kg
Alopiidae	Alopias	ONOE0109	<i>A. vulpinus</i>	12 mm	162.7 cm	10 kg
Dasyatidae	Dasyatis	ONOE0110	<i>D. Akajei</i>	4 mm	63 cm	1.8 kg

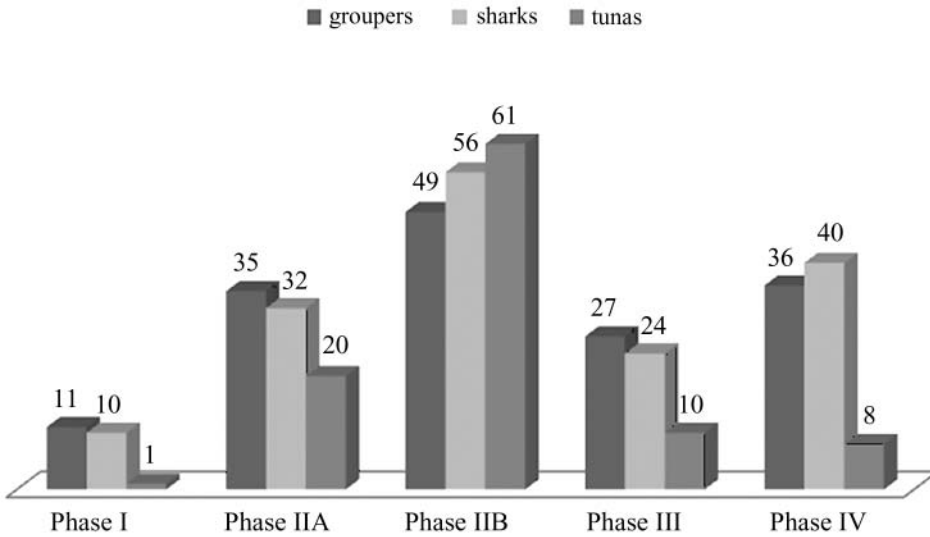


Figure 3. Temporal distribution for MNI of groupers, sharks, and tunas.

fish taxa during all phases does not appear to change much (the relative abundance of both families remains around 20% [see Figure 4]), the statistics provided in Table 7 show that the adjusted residuals of groupers decrease significantly from Phase IIA to

Phase IIB ($-9.2729, p < .000$), and significantly increase from Phase IIB to Phase III ($8.2112, p < .000^8$). In contrast, the adjusted residuals of sharks (Carcharhinids) increase significantly from Phase IIA to Phase IIB ($2.1963, p = .0281$) and continue to increase

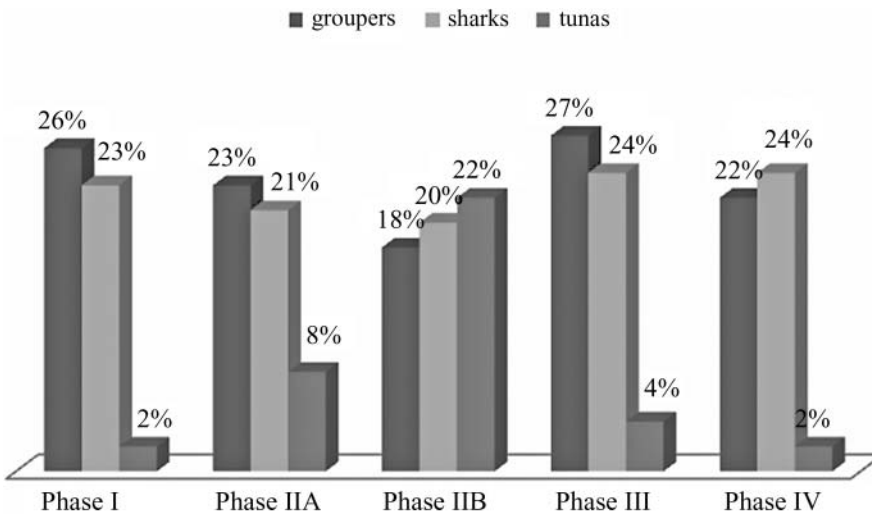


Figure 4. Temporal change of groupers, sharks, and tuna ratio in total MNI.

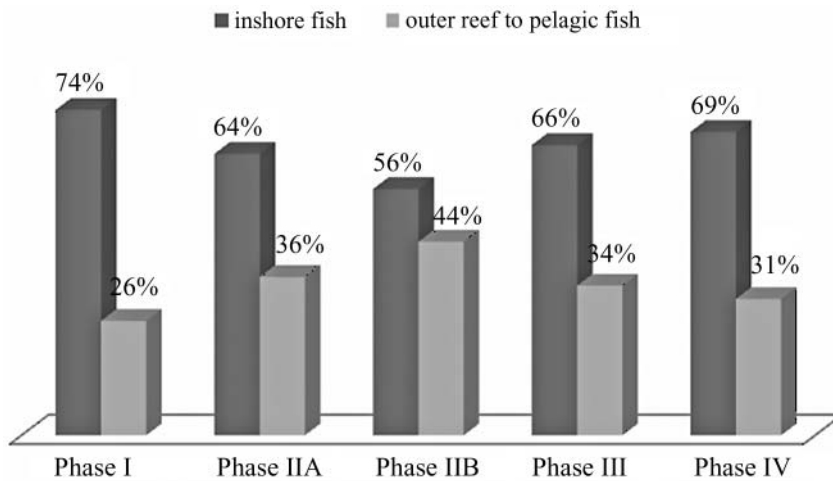


Figure 5. Temporal distribution of offshore versus inshore fish ratio (MNI).

from Phase IIB to Phase III (3.8968, $p = .001$). However, shark (Carcharhinids) decrease from Phase III to Phase IV (-3.0591 , $p = .001$). Although our fish bone analysis confirms that both groupers and sharks were continually exploited major fish resources from the early stage of colonization into the late prehistoric period, statistical analysis indicates that the abundance of groupers and sharks have also changed significantly during these phases.

The statistical analysis also shows a very clear change in the temporal pattern of tuna capture. The % MNI of tuna during Phase I was very small, but substantially increased during Phase IIA (AD 400 to 600) and IIB (AD 600 to 800), then dramatically decreased in Phases III and IV. Phases III and Phases IV likely post-date AD 1200 (see also Table 4). The statistical analysis also supports the MNI analysis of Scombrid temporal patterns discussed above (see Table 7). The reasons for the dramatic increase and decrease in the numbers of tuna are unclear, though the increase in the number of tuna bones during Phase II possibly is related to potential population growth as the numbers of other fish taxa and of excavated artifacts also increased during Phase II, or possibly to the emergence of new fishing technology to catch tuna in

Fais. The dramatic increase in the number of tuna might also be affected by climatic change during this phase, though there are currently insufficient data to support this claim.

In terms of the first factor, the analysis of mammal remains also confirmed that pig and dog exploitation increased in Phase II (see Table 3). The number of other artifacts also increased during Phase II, and fishhooks appeared from Phase IIB (Table 3) which corresponds to the dramatic increase in the number of tuna; the MNI ratio of offshore species (44%) is almost in equilibrium to that of inshore fish (56%) during this phase (Figure 5). We should emphasize again that this drastic increase in numbers of bones and other artifacts during Phase II (A and B) is clearly independent from the total excavation volume in each phase as described above (see also Table 3). If the majority of offshore species (mainly sharks and tunas) are middle- to large-bodied fish, while inshore species are mostly relatively smaller-bodied fish, as we roughly estimate, the actual value of offshore species as a protein source was possibly much higher than that of inshore species, particularly during this time.

Although the production and use of fishhooks might have some effect on the

dramatic increase in the number of tuna, trolling lures, which could be directly related to tuna and pelagic fishing (e.g., Davidson et al. 1999; Johannes 1981; Kirch and Dye 1979; Leach et al. 1988, 1994) were not found from Phase I and II in our 2005 excavation. All of the lure shanks were excavated from Phase III (see Table 3). However, a single pearl shell (*Pinctada maxima*) lure shank was excavated from Phase II at FSPO2 during the 1991 excavation (Intoh 1997) tentatively indicating it might have been used at least during Phase II. Alternatively, the increase in lure shanks during Phase III at the site contradicts the fish bone analysis, which indicates a drastic decrease in the number of tuna after this phase. Yet, it is unclear whether these shanks were produced and used for fishing during Phase III, as some lure shanks have a hole through the head part and might be breast or ear ornaments that could have been curated from Phase II. It is also possible that they are re-used old items originally made and used during Phase II.

After Phase III, the number (both NISP and MNI) of tuna rapidly declines. Although it is uncertain why only tuna exploitation dramatically declined, cultural change (e.g., dietary preference or social control on tuna consumption or exploitation) or social development (e.g., the possibility that only elites had access to tuna as a special resource) might be involved in the drastic decrease in the number of tuna at this one site. To approach the potential factor(s) of such drastic changes, we need to investigate both anthropogenic and non-anthropogenic factors and changes particularly in marine ecosystems (see also Reitz et al. 2009).

In terms of anthropogenic or cultural change, inshore to offshore species, including sharks, groupers, and other major fishes, were continually exploited during later phases and it is curious that only tuna were neglected or not allowed to be caught during these phases. As for social development, stratified chiefdoms are thought to have developed after around AD 1200 in some Polynesian islands (e.g., Kirch 1989). While the existence of such high-ranked chiefdoms or highly classified societies was

observed on some islands in Micronesia such as Yap, Kosrae, and Pohnpei, possibly after the late prehistoric times around AD 1200 (e.g., Athens 1981; Ayres 1983; Cordy 1985, 1993), there is no ethnographic or archaeological evidence yet to suggest that a highly stratified society had been developed on the raised coral islands in the Carolines (e.g., Alkire 1978). All such trends tentatively indicate that the dramatic decrease in the number of tuna might not directly relate to the anthropogenic changes; but, we need additional archaeological data to investigate various aspects and changes of anthropogenic events over time on Fais.

On the other hand, in terms of non-anthropogenic changes, possible changes in climate, marine ecology, or resource accessibility in the later phases on Fais could be potential reasons for the drastic decrease of tunas as they are a highly migratory pelagic species. For change in climate and marine ecology, many scholars portend that there was a period of global cooling starting around AD 1300 and 1500 (the Little Ice Age) and lasting until about 1850 (e.g., Fagan 2000; Lamb 1995; Thompson and Mosley-Thompson 1987). The LIA also coincides with what Nunn and others (Nunn 1999, 2000a, 2000b, 2003; 2007; Nunn et al. 2007) refer to as the “AD 1300 Event”, a perceived pan-Pacific “environmental catastrophe” which he suggests occurred between AD 1270 and 1475, representing the transition from the Little Climatic Optimum (Medieval Warm Period, MWP) to the LIA as a cool, dry period with increased storminess between AD 1350 and 1850.⁹ The paleoclimatic proxy records taken from long-lived corals in the equatorial Pacific indicate a different pattern, with a shift from relatively cooler conditions sometime after AD 1200 and a marked warm interval around AD 1300 (Allen 2006; Cobb et al. 2003a, 2003b). As such, it is unclear whether Nunn’s (1999, 2003) model can be applied across the Pacific as a whole, particularly given discrepancies in the archaeological record which show the inverse of what is proposed (e.g., see Fitzpatrick 2010).

In terms of the relationship between tuna biology and climate, their migratory

patterns are closely governed by ocean processes that create a conjunction between suitable physical habitat (e.g., temperatures and adequate oxygen) and adequate food sources (Miller 2007:60). As tuna are constantly swimming in search of food, the areas of tuna concentration are by no means casual, and migration takes place according to hydrological routes in which each species finds the optimum environment for survival in every stage of its existence (Stequert and Marsac 1989:67).

Tropical tuna, including skipjack and yellowfin, tend to be fast-growing and relatively short-lived. A feature of the central equatorial Pacific is a strong divergent equatorial upwelling called the cold tongue which is favorable to the development of a large zonal band with high levels of primary production (Miller 2007). Contiguous to the cold tongue is the western Pacific warm pool which is characterized by warmer water with lower levels of primary production. At the top of the food web, the tropical tuna are a major component of the pelagic ecosystem and have their maximum biomass in the warm pool. However, during ENSO (El Niño Southern Oscillation) events, variability is observed in both environmental factors and the spatial distribution of tuna (Lehodey 2001).

In the central and western Pacific, for example, recruitment of tropical tuna increases during El Niño, and there is a pronounced eastward displacement of those stocks (Lehodey et al. 2003).¹⁰ El Niño events also affect the distribution of tuna stocks in the eastern Pacific and Indian Oceans (Marsac and Blanc 1998; Suarez-Sanchez et al. 2004). In terms of skipjack, the cold tongue and the associated zone of high skipjack abundance retreat eastward, by as much as 4,000 km depending on the intensity of the El Niño event (Lehodey et al. 1997). Meanwhile the wind stress anomaly associated with the El Niño causes coastal upwelling to develop along the north coast of Papua New Guinea, favoring an increase of primary production in the far western Pacific. The resulting excellent feeding and recruitment conditions cause a pulse of high skipjack abundance at the far western edge of the Tropical

Pacific when the El Niño fades (Lehodey 2001).¹¹

Although the relation between ENSO and tuna biology is over relatively short time periods (10–20 years), they indicate that climate variability has a demonstrable impact on the abundance, concentration, location, and catchability of tropical tuna stocks. For Fais, recent data from long-lived Pacific corals (e.g., Cobb et al. 2003a, 2003b; Moy et al. 2002a, 2002b) as well as Nunn's model (2000a, 2000b, 2003) tentatively indicate that a pronounced decline in tuna around AD 1200 could correspond to active ENSO or cooler temperatures during this time, although there is as yet no palaeoclimate model that might explain a drastic increase in tuna after AD 400 in the island. It is uncertain whether the increase of tuna numbers on Fais relates to non-anthropogenic change(s) such as climatic change, anthropogenic factor(s) including technological, cultural, and social changes, or both factors, and more archaeological data and paleoclimate records for the past 2,000 years are needed to resolve this issue.

Considering the possible change in resource accessibility, there is another possibility: that the decline of material resources for building canoes or other fishing gear relating to tuna fishing may have caused the decrease in tuna exploitation. For example, a decline of certain shell species such as the *Trochus* and pearl shell used for making lures might cause a decrease in tuna capture. However, as discussed above, our excavations of trolling lure at FSPO do not support this possibility, as more trolling shanks were excavated from Phase III (low tuna MNI) rather than Phase II at the site (high tuna MNI).

In terms of a possible connection with canoe building, the hypothesized shortage of large trees suitable for building canoes (particularly sailing canoes for offshore trolling) could have occurred on Fais because of the island's small size and its very limited land and forest resources, especially after a potential population increase during Phase II. Also, a larger sailing canoe¹² is usually required for offshore trolling (e.g., Nason 1975:13) to catch tuna. To confirm such a possibility,

we need palaeoecological data for landscape change on Fais. However, the fact that sharks were continually exploited even after AD 1200 indicates that people had access at least to the outer-reef zone to catch sharks, possibly by paddling canoes.¹³

The continual capture of sharks after AD 1200 at FSPO can also be one of the important findings when we discuss the possible climate and marine environmental changes of the past, as most shark species are not migratory fish like tuna, and thus might not be affected so much by such changes. Shark fishing does not require sailing canoes for trolling or trolling lures either. One traditional shark fishing method on Fais uses only a large plant-fiber (mainly coconut) noose and plant-made rattle (e.g., cane-made hoop and some pieces of coconut shells); hence the capture of sharks might not be much affected by any decline in material resources. Overall, the exact factors involved in the dramatic decrease in the number of tuna remains uncertain, though the sharp contrast between tuna and shark exploitation could be an important clue to finding out why only tuna seemingly disappeared from the major catch in prehistoric Fais.

DISCUSSION

The Character of Prehistoric Fais Fishing in the Oceanic Context

The number of fish bones recovered and identified from archaeological sites in Fais is larger than that from many other prehistoric sites in Oceania. The character and strategy of Fais fishing is also unique compared with prehistoric fishing on other islands in Oceania. The intensive catching of sharks is one of the prominent aspects of both prehistoric and contemporary Fais fishing, though shark fishing itself is not unusual in Oceania (e.g., Bayliss-Smith 1990; Chikamori 1988; Christiansen 1975; Dye 1983; Johannes 1981; Leach and Davidson 1988; Leach et al. 1988; O'Connell 1972; Ono 2008; Ono and Addison 2009; Ruhen 1986).

Although ethnographic information collected in Oceania shows that there are various methods of catching sharks, the main methods are: a) baited line fishing; and b) noosing with a plant fiber-made string and rattle(s) occasionally in outer-reef to pelagic zones (e.g., Bayliss-Smith 1990; Chikamori 1988; Christiansen 1975; Dye 1988; Johannes 1981; Ruhen 1986; Vaea and Straatmans 1954), and it could be that similar methods were used in prehistoric times. Our informal interviews with islanders ($n = 5$) in 2005 confirmed that they used both methods in the recent past, though they now only use line fishing to catch sharks and fishing with a noose is no longer in use. It is worth noting that people on Fais still catch and eat sharks today.

Similarly, the major method of catching groupers today is baited line fishing, as these fish inhabit the sea bottom along the inner-reefs and deep sea down to about 100 m in depth (e.g., Kirch and Dye 1979; Leach et al. 1988, 1996; Masse 1989; Ono 2006, 2007, 2009, 2010). As discussed above, most identified groupers might belong to smaller bodied specimens and such evidence tentatively indicates that these groupers were possibly captured on reefs or close to the reefs around Fais rather than in deeper seas.

Other various inshore fish species from the sites also indicate that intensive inshore fishing on reef zones was occasionally practiced by islanders in the past. Our brief observations in 2005 confirmed that most of the small inshore fish were captured individually by net fishing (although a cast net was used which might have been introduced to the island after the nineteenth century). When the archaeological data and ethnographic information are combined, the basic fishing strategy in Fais can be characterized as the intensive exploitation of offshore species, including sharks and tuna, along with daily or occasional exploitation of inshore species along coastal zones with no lagoon. The results in FSPO clearly show that these basic fishing strategies were practiced from the earliest phase (AD 200 to 400) and continued during the prehistoric period, while only the number of tuna dropped possibly after AD 1200. The excavations of other sites formed

during Phase III and IV in Fais also found limited numbers of tuna bones, confirming such a trend (Intoh and Ono n.d.; Leach et al. 1994).

In terms of shark exploitation, many prehistoric sites produced shark bones, while there are also sites with few shark bones in Oceania (Table 12). Shark fishing is culturally prohibited or abandoned among some islands and societies in Oceania today (e.g., Bates and Abbott 1958:54; Fischer 1957:100; Ruhen 1986:108-109). Certainly, the prominent aspect of Fais fishing is its heavy dependence on sharks as a protein source. The percentage of shark remains in FSPO from the total MNI is much greater than that at other sites in other parts of Oceania, including Polynesia.

The second characteristic of prehistoric fishing on Fais was the intensive exploitation of groupers and tunas. The percentage of groupers in FSPO from the total MNI is also much greater than that found at other sites in Oceania, while that of tunas is high and similar to some Polynesian islands (see Table 12). The table also shows the large number and volume of groupers and tunas that tend to be caught at sites mainly located in raised coral and atoll islands with limited fringing-reef environments, such as Fais and Tobi (raised coral islands) or Ebon and Kapingamarangi (atolls) in Micronesia, as well as some volcanic islands and atolls in the Marquesas Group, Austral Group, and Tokelau Group in Polynesia.

Larger to middle-bodied groupers are usually captured by baited-line fishing, while tunas are mainly caught by trolling with baited hooks and particularly lures. This tentatively suggests that angling methods with baited hooks could have played an important role in Oceanic islands with relatively limited reef and lagoon environments. Other fishing methods with some types of nets, spears, plant poisons, and possibly baskets were also employed mainly to catch inshore species such as parrotfish, triggerfish, emperors, wrasses, and unicornfish. Among emperors, some larger species such as *Monotaxis granoculis* which prefer to inhabit much deeper zones close to shore were possibly caught by baited hooks. Wrasses and triggerfish are

also caught by angling, but some wrasse species can also be captured by netting and poisoning (e.g., Masse 1986, 1989; Ono 2006, 2007, 2009, 2010), while triggerfish can be caught by basket trapping, spearing, and netting (e.g., Kirch and Dye 1979; Masse 1986; Ono 2006, 2007, 2009, 2010).

In general, the high percentage of tunas in the total number of fish bones during the period AD 400 to 800, as well as the high percentage of sharks in prehistoric times, strongly indicates heavy offshore exploitation in Fais. Although our size analysis of the excavated vertebrae is tentative, it clearly indicates that these offshore fish species on Fais might also be more important as a protein source than other inshore fish species, including groupers.

While not dependent only on tunas, a similar trend toward heavy offshore exploitation is also seen in prehistoric Rota (Leach et al. 1988) and Guam (Amesbury 2008; Leach and Davidson 2006a, 2006b) in the Mariana Islands. Among these islands Rota has poorly developed reef environments, while Guam has some reef shores around the island. At the Mangilao golf course site in Guam, nearly 23% of the MNI belong to the pelagic fish species, including Coryphaenidae, Istiophoridae/Xiphiidae, and Scombridae, while at the Mochon site 16.9% of the total MNI belongs to offshore species and 33.6% of bones from the Airport site in Rota are offshore species (Amesbury 2008). Among some volcanic islands without rich-reef environments in Polynesia such as the Marquesas, the percentage of offshore species is similarly high. Pelagic species represent about 55% of the total number of fish bones in Hanamiai (Rolett 1989:372), as well as 46% in Hane (Davidson et al. 1999) and 32% in Anapua (Leach et al. 1997). These data, along with those from Fais, may suggest the importance of offshore resources as a protein source among such islands with limited reef environments.

Temporal Change in Pelagic Exploitation in Fais

Another characteristic of prehistoric fishing in Fais is the temporal catch change

Table 12. Percentage of elasmobranchs, groupers, and tunas at each site/island, Oceania.

Site/island	Islands/group	Elasmobranch	Serranidae	Scombridae	Reference
FSPO/Fais	Yap	21.5% (162)	21.2% (158)	11.1% (100)	This paper
Tobi	SW Palau	16.1% (6)	15.1% (5)	6.5% (2)	Intoh and Ono 2006
Rurutu	Austral	10.7% (3)	14.3% (4)	3.6% (1)	Leach et al. 1984a
Nukuoro	Pohnpei (atoll)	9% (62)	9% (62)	7.3% (50)	Leach and Davidson 1984
Hanamiai	Marquesas	?	6.3% (31)*	17.6% (87)*	Rolett 1989
Hane	Marquesas	6.8% (36)	15.8% (84)	25.7% (137)	Leach et al. 1984b
Fakaofu	Tokelau (atoll)	5.3% (7)**	14% (515)*	0.1% (5)***	McAlister 2002
Fa'ahia	Society	1.3% (5)	8.8% (33)	20% (73)	Leach et al. 1984a, 1984b
EKQ/Mussau	Bismarck	?	7.2% (25)*	9.8% (34)*	Butler 1994
Kapingamarangi	Pohnpei (atoll)	4.3% (52)	19% (231)	5% (61)	Leach and Davidson 1988
Nan Madol A	Pohnpei	4.2% (51)	7.5% (91)	1.2% (15)	Leach et al. 1993
Mangilao/Guam	Mariana	3.8% (10)	4.1% (11)	0.8% (2)	Leach and Davidson 2006a
Anapia	Marquesas	3.6% (16)	12.7% (56)	24.8% (109)	Leach et al. 1997
RF2/Main Reef	Santa Cruz	1.5% (3)	9.7% (20)	1.5% (3)	Green 1986
Motupore	New Guinea	2.3% (10)	5.9% (31)	7.4% (39)	Allen 1986
Ylig Bay/Guam	Mariana	2.1% (2)	6.3% (6)	0% (0)	Amesbury 2008
Tachonga/Tinian	Mariana	1.6% (5)	7.9% (24)	1% (3)	Amesbury 2008
Ebon atoll	Marshall	1.6% (12)	7.5% (55)	0% (0)	Bilton 2001
ECA/Mussau	Bismarck	?	6.5% (207)*	1.3% (42)*	Butler 1994
TK-4/Tikopia	Santa Cruz	?	3.6% (41)*	0.3% (3)*	Kirch and Yen 1982
Mochong/Rota	Mariana	1% (3)	9.6% (30)	0.6% (2)	Leach et al. 1988
Chelechol ra Orrak	Palau	1% (2)	11.5% (21)	0% (0)	Fitzpatrick and Kataoka 2005
Rock Islands	Palau	?	5.7% (133)	1.9% (44)	Masse 1986
Rapa	Austral	1% (5)	11% (56)	0% (0)	Vogel 2005
SIU/Rota	Mariana	0% (0)	8.7% (16)	6.5% (12)	Davidson and Leach 1984
Pagat/Guam	Mariana	0% (0)	6% (11)	0% (0)	Craft 1986
NT-90/Niuaotupapu	Tonga	?	0% (0)	0% (0)	Kirch 1988

*Based on NISP value.

**MNI in TPI re-counted by ONO including vertebrae, while MNI counted by McAlister is "1" (0.8%).

***MNI counted by McAlister, but without all vertebrae possibly identified as Scombridae (McAlister 2002:60).

in pelagic fish species, especially for tunas which as noted previously, are highly migratory fish. Although the exact reasons for intensive tunas exploitation and the sudden decline of exploitation after AD 1200 are unclear, as Allen (2006:530) asserts, marine fauna may have a key role to play in evaluating the occurrence and timing of climate change and its effects on prehistoric Pacific people.

In Palau, for instance, Masse and colleagues investigated changes in marine and animal use as well as paleoenvironmental coring data dated to around AD 1200 to 1600, which indicates the possible influence of climatic change in Palau (Masse et al. 2006). As a result, they confirm an increase in the capture of inshore species such as parrotfish, porcupinefish, and wrasses, with a corresponding decline in the capture of inshore to offshore fish species such as squirrelfish (Holocentridae), snappers, emperors, and sea breams (*Monotaxis* spp.), as well as pelagic species such as skipjack tuna and jacks (Carangidae) during AD 1200 to 1600 compared with the preceding period. They also suggest that pigs were common, at least on rock islands, in Palau from AD 650 to 1450, but had begun to decline in number from around AD 1200, and were finally extirpated at some point between AD 1450 and 1650 (Masse et al. 2006:121).¹⁴

Similarly in the Marquesas, Rolett reported that the percentage of pelagic fish species (especially tuna) dramatically decreased, while the percentage of inshore species increased after AD 1250 in Hanamiai (Rolett 1989:373). In Anapua, there appeared to be a decline in tuna fishing and an increase in grouper fishing over time (Leach et al. 1997:54, 63). Such a decline in tuna fishing is similarly confirmed in Hane as tunas occupied about 26% of total MNI during the early phase, but declined to about 16% during the late phase. It is also true that tunas were still an important component of the catch by Hane fishermen and that they were also catching a wider range of fish species than before (Davidson et al. 1999:18). At any rate, it is clear that tuna exploitation declined among the Marquesas Islands, mainly after AD 1200, while people continued to catch various other fish, especially inshore species.

These archaeological data clearly indicate that something happened to pelagic resource exploitation in the Pacific, especially tunas, after AD 1200.

In terms of temporal change in inshore fishes in Fais, the percentages of inshore fish species in total MNI or NISP do not show any dramatic changes from the early phases to later phases at FSPO except for a few families such as groupers, triggerfish, snappers, and emperors. As shown in Figure 6 for instance, the percentage of triggerfish in total MNI during Phase I was about 18%, while its percentage declined to 10% in Phase IIA and IIB. The statistic analysis also shows such drastic decline of triggerfish from Phase I to Phase IIA (-3.4420 , $p < .001$) and then to Phase IIB (-5.5258 , $p < .001$), while the relative abundance of them increase during Phase III and IV (see Table 7).

The similar trends are also confirmed for groupers, snappers, and emperors as shown in Tables 4 and 7. Particularly, the increase of groupers and emperors from Phase IIB to Phase III dated to after AD 1200 looks dramatic in Tables 4 and 7. In Leach's study, an increase in snapper numbers around AD 1300 to 1400 is observed in New Zealand, although the number and percentage of snappers again decreased after AD 1600 (Leach 2006:180). To explain these changes, Leach (2006:229–231) suggests that the Climatic Optimum during AD 1200 to 1500, and the LIA during AD 1600 to 1800 in New Zealand are possible factors in the increase and decrease of snapper, as well as of some other fishes.

Although New Zealand is located in the Southern Hemisphere and does not directly correspond to Fais and other tropical islands in the central Pacific, it appears plausible that climate change can affect the distribution and numbers of fish species in the past. Such variation is apparent across the region and latitudinally, reflecting the complex ocean-atmosphere relations that operate in the Pacific Ocean. However, as Allen (2006: 529) continues to point out, some parts of the Pacific basin, particularly the northern Pacific including Micronesia, remain poorly known with few palaeoclimate records, and

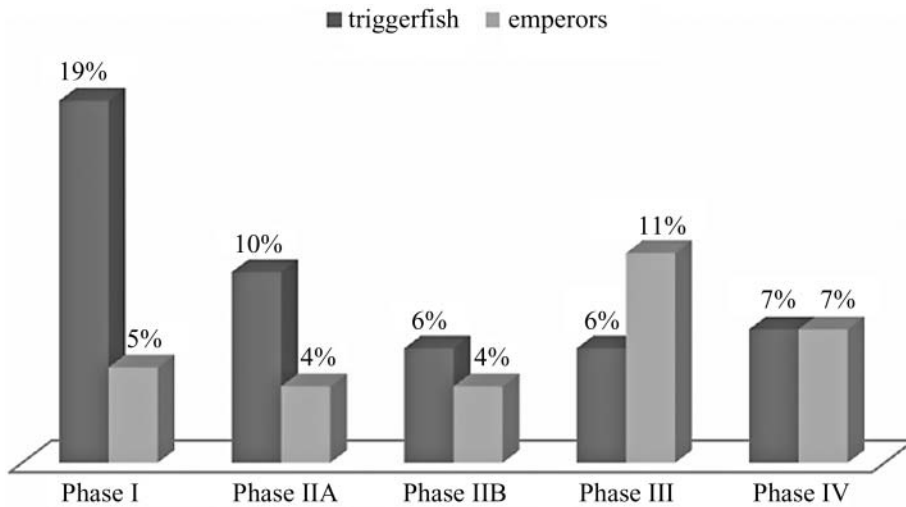


Figure 6. Temporal change of triggerfish and emperors ratio in total MNI.

we need further studies to collect more data.

Finally, it is worth recommending again that vertebrae be incorporated into analysis, especially for identification of elasmobranch and pelagic fish such as tunas. The past studies of excavated fish bones in Oceania neglected vertebrae in their analysis, with a few exceptions (e.g., Davidson et al. 1999; Leach et al. 1994, 1997). As our study shows, however, vertebrae analysis for fish identification increases both NISP and MNI of sharks and tunas. For identification of tuna, use of the caudal peduncle is also important as this element plays an important role in increasing MNI (see also Davidson et al. 1999). Such evidence clearly indicates that vertebrae analysis is essential to evaluate the actual value of each fish species in the past and also to reconstruct prehistoric fishing activities and strategies more precisely.

In addition, size analysis of vertebrae and other cranial bones may also be required to evaluate actual value (or meat weights) of each fish species or more simply to compare pelagic fish with inshore fish taxa, as well as to estimate or reconstruct possible fishing method of capture (e.g., Ono 2010; Ono and Clark n.d.; Reitz et al. 2009:17). Although our

tentative analysis of vertebrae size and rough comparison with the reference collection here is still in progress, it indicates the possibility that offshore fish (sharks and tuna) were far more important than inshore fish as a protein source in the case of Fais. On the other hand, as for groupers, if the majority of specimens tend to be smaller in size, the actual meat weights could be lower than that of other major fishes, even if the MNI count is one of the largest. To avoid these risks, we strongly recommend conducting and developing vertebra and other cranial bone size analysis in future studies. Once this type of analysis is conducted on fish bone assemblages from Oceania, we should be able to reconstruct the past changes of fish exploitation and fishing strategies in much greater detail.

ACKNOWLEDGEMENTS

Research permits to conduct an archaeological survey on Fais in 2005 were provided by the Yap Historic Preservation Office (headed by James Lukan) and by Luis, Chief of Fais Island, to whom we are grateful. The 2005 research was carried out as a part of the project "Selective

use of Natural Resources and Symbolization" funded by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research on Priority Areas to Intob. We would like to express our sincere appreciation to Joe Maregior and Meggie Yukurman for their great hospitality and fishing knowledge and to all the others on Fais who always support us with enthusiasm in our efforts to understand their ancient history. We also owe many thanks to Don Rubinstein, who shared his anthropological knowledge of Fais; Nobuo Shigebara, who identified the mammal remains; and Shyo Tanaka, who donated shark vertebrae references. We are indebted to Geoff Clark, David Addison, and Alex Morrison who reviewed earlier drafts and provided invaluable comments and editorial suggestions. Comments by two anonymous referees were also very helpful. Any errors, however, remain our own.

END NOTES

1. Kaneko and Saito (1980), for instance, analyzed 18 shark species (9 families) and calculated the mean total number of vertebrae for each species to show that most of these species produce over 100 vertebrae. They also concluded that the number of total vertebrae for shallow-water species tend to be larger than for deep-water species (see also Springer and Garrick 1964).
2. In most sharks the monospondyly centra (head to middle) gradually increase in length from the cranium posteriorly, and thus these centra are usually longest, while the diplospondyly part (middle to tail) tends to be shortest (Springer and Garrick 1964:76). However, its size pattern shows great differences between species. For instance, the maximum and minimum size (diameter) of a *Carcharbinus longimanus* specimen measured 19 mm and 5 mm, while those of a *Prionace glauca* specimen measured 11 mm and 10 mm respectively (Kaneko and Saito 1980).
3. Besides such organized contacts with nearby coral islands and a high island, accidental contacts with other islands cannot be ignored. In 1664 alone, Father Andrea Serrano in the Philippines recorded 30 canoes that drifted from the Carolines. In 1697, Clain described 29 Carolinians on Samar Island in the Philippines who had been blown to the west in two canoes (Hezel 1979).
4. The FSPO site was previously excavated during the 1991 phase of research (FSPO-2).
5. This analysis was done with NISP rather than MNI to take advantage of the larger sample size.
6. The fish bone assemblage from FSPO-2 (1991 research) by Leach and others also identified *Carcharbinus falcifo* and *Carcharbinus galapag* (Leach et al. 1994).
7. These references were originally collected around Ogasawara Islands in southwestern Japan (Pacific), in close proximity to the Mariana Islands in Micronesia. They were then measured and identified by Dr. Shyo Tanaka of Tokai University, an expert in elasmobranch studies, and donated to Ono in 2007.
8. The chi square analysis is done with NISP rather than MNI. The result of tuna seems very robust since both MNI and NISP are capturing the difference.
9. Within this 200-year time span Nunn (2003) has identified two separate periods of environmental flux involving a decrease in temperatures, the lowering of sea level, increased storminess, and a short-lived rise in precipitation. Stage 1 occurs between AD 1270 and 1325, while Stage 2 occurs around AD 1455-1475.
10. However, albacore (*Tbunnus alalunga*), a subtropical species, shows the opposite pattern of low recruitment during El Niño and high recruitment during La Niña (Lehodey et al. 2003).
11. Based on the Spatial Ecosystem and Populations Dynamics Model, Lehodey (2001) further explains that simulations reproduced skipjack recruitment increases in both the central and western Pacific during El Niño events as a result of four mechanisms: the extension of warm water farther east; enhanced food for tuna larvae; lower predation of tuna larvae; and retention of the larvae in these favorable areas as a result of ocean currents. The situation is reversed during La Niña events, when westward movement of cold waters reduces spawning success in the central Pacific. Then the bulk of recruitment is centered in the warm waters of the western Pacific. Results are more preliminary for yellowfin, but similar mechanisms likely occur for this species and peaks of recruitment

are predicted after each major El Niño event (Lehodesy 2001).

12. Nason (1975:15) recorded that sailing canoes were normally larger (8 to 12 m in length) than paddling canoes (3 to 8 m long) on Etal Island in the eastern Caroline Islands before 1964.
13. For example, Ruhen reported that he observed a local man on a small paddling out-rigger canoe catch a grey nurse shark (*Eugomphodus Taurus*), which was 3 m long and far longer than the canoe, by noosing method on outer-reef zone in Kiriwina Island, one of islands among Trobriand Islands in the Solomon, during the 1950s (Ruhen 1986:106-107).
14. Although the faunal data clearly demonstrate the potential relationship between climate and culture change in Palau, they also find no identifiable signature for vegetation change corresponding to the onset of the LIA, and suggest that a greater emphasis on high-resolution data is necessary to properly evaluate the role of climate in Pacific island culture change (Fitzpatrick 2010; Masse et al. 2006:128; Ono and Clark n.d.).

REFERENCES

- Alkire, W. H. 1978. *Coral Islanders*. Arlington Heights: AHM Publishing.
- Allen, J. 1986. Fishing without fish hooks. In *Traditional Fishing in the Pacific* (A. Anderson, ed.):19-35. Pacific Anthropological Records 37.
- Allen, M. S. 2006. New ideas about late Holocene climate variability in the Central Pacific. *Current Anthropology* 47:521-535.
- Amesbury, J. 2008. Pelagic fishing in prehistoric Guam, Mariana Islands. *Pelagic Fisheries Research Program* 13(2):4-8.
- Athens, J. S. 1981. *The Discovery and Archaeological Investigations of Nan Madol, Ponape, Eastern Caroline Islands: An Annotated Bibliography*. Micronesian Archaeological Survey Report 3. Saipan: Office of Historic Preservation, Trust Territory of the Pacific Islands.
- Ayres, W. S. 1983. Archaeology at Nan Madol. Ponape. *Bulletin of the Indo-Pacific Prehistory Association* 4:135-142.
- Bates, M. and D. P. Abbott. 1958. *Ifaluk: Portrait of a Coral Island*. London: Museum Press Limited.
- Bayliss-Smith, T. 1990. Atoll production systems: Fish and fishing on Ontong Java Atoll, Solomon Islands. In *Pacific Production Systems: Approaches to Economic Prehistory* (D. Yen and M. J. Mummery, eds.):57-69. Occasional Papers in Prehistory 18. Canberra: The Australian National University.
- Bellwood, P. 1978. *Man's Conquest of the Pacific: The Prehistory of Southeast Asia and Oceania*. Auckland: Collins.
- Bender, B. 1971. Micronesian languages. In *Current Trends in Linguistics* (T. A. Sebeok, ed.):pp. 426-465. Linguistics in Oceania, Vol. 8. The Hague: Mouton.
- Bilton, M. 2001. *Taphonomic Bias in Pacific Ichthyoarchaeological Assemblages: A Marshall Islands Example*. M.A. Thesis. Dunedin: University of Otago.
- Blust, R. 1984. Malaita-Micronesian: An eastern Oceanic subgroup? *The Journal of the Polynesian Society* 93:99-140.
- Butler, V. L. 1994. Fish feeding behavior and fish capture: The case for variation in Lapita fishing strategies. *Archaeology in Oceania* 29:81-90.
- Chaplin, R. E. 1971. *The Study of Animal Bones from Archaeological Sites*. London: Seminar Press.
- Chikamori, M. 1988. *Ethno-Archaeology in a Coral Reef Island*. Tokyo: Yuzankaku Press (in Japanese).
- Cobb, K. M., C. D. Charles, H. Cheng, and R. L. Edwards. 2003a. El Niño/Southern Oscillation and tropical Pacific climate during the last millennium. *Nature* 424:271-76.
- Christiansen, S. 1975. *Bellona Island; Economic Conditions; Economic Anthropology; Shifting Cultivation; Industries, Primitive; Solomon Islands*. Copenhagen: National Museum of Denmark in cooperation with the Royal Danish Geographical Society.
- Cobb, K. M., C. D. Charles, H. Cheng, M. Kastner, and R. L. Edwards. 2003b. U / Th-dating living and young fossil corals from the central tropical Pacific. *Earth and Planetary Science Letters* 210:91-103.
- Cordy, R. 1985. Settlement patterns of complex societies in the Pacific. *New Zealand Journal of Archaeology* 7:159-182.
- Cordy, R. 1993. *The Lelu Stone Ruins (Kosrae, Micronesia): 1978-81 Historical and Archaeological Research*. Asian and Pacific Archaeology Series 10. Honolulu: Social Science Research Institute, University of Hawaii.
- Craib, J. L. 1986. *Casas de Los Antiguos: Social Differentiation in Protobhistoric Chamorro Society, Mariana Islands*. Ph.D. Thesis. Sydney: University of Sydney.
- Davidson, J. M. and B. F. Leach. 1984. Fish bone. In *Archaeological Investigations on the North Coast of Rota, Mariana Islands* (B. M. Butler, ed.):335-356. Carbondale: Micronesian

- Archaeological Survey Report No. 23 and Southern Illinois University at Carbondale Center for Archaeological Investigations Occasional Paper No. 8.
- Davidson, J. M., K. Fraser, B. F. Leach, and Y. H. Sinoto 1999. Prehistoric fishing at Hane, Ua Huka, Marquesas Islands, French Polynesia. *New Zealand Journal of Archaeology* 21:5-28.
- Descantes, C. 2005 *Integrating Archaeology and Ethnohistory: The Development of Exchange between Yap and Ulithi, Western Caroline Islands*. BAR International Series 1344. Oxford: BAR.
- Dye, T. 1983. Fish and fishing on Niuatoputapu, Tonga. *Oceania* 53:242-271.
- Everitt, B. S. 1977. *The Analysis of Contingency Tables*. London: Chapman and Hall.
- Fagan, B. 2000. *The Little Ice Age: How Climate Made History, 1300-1850*. New York: Basic Books.
- Fischer, J. L. 1957. *The Eastern Carolines*. New Haven: HRAF Press.
- Fitzpatrick, S. and O. Kataoka 2005. Prehistoric fishing in Palau, Micronesia: Evidence from the northern Rock Islands. *Archaeology in Oceania* 40:1-13.
- Fitzpatrick, S. M. 2010. A critique of the 'AD 1300 event', with particular reference to Palau. *Journal of Pacific Archaeology* 1(2):1-6.
- Grayson, K. D., and F. Delepech 2003. Ungulates and the Middle-to-Upper Paleolithic transition at Grotte XVI (Dordogne, France). *Journal of Archaeological Science* 30:1633-1648.
- Green, R. C. 1986. Lapita fishing: The evidence of site SE-RF-2 from the main Reef Islands, Santa Cruz group, Solomons. In *Traditional Fishing in the Pacific* (A. Anderson, ed.):19-35. Pacific Anthropological Records 37.
- Hezel, F. X. 1979. *Foreign Ships in Micronesia: A Compendium of Ship Contacts with the Caroline and Marshall Islands, 1521-1885*. Saipan: F. J. Hezel and Trust Territory Historic Preservation Office.
- Hunter-Anderson, R. and Y. Zan 1996. Demystifying the Sawei, a traditional interisland exchange system. *ISLA Journal of Micronesian Studies* 4(1):1-45.
- Intoh, M. 1993. Archaeological research on Fais Island: Preliminary report. In *Cultural Anthropological Research on Historic Media in the Caroline Islands* (K. Komatsu, ed.):69-111. Committee for Micronesian Research 1991. Osaka: Osaka University.
- Intoh, M. 1995. *The Acceptance of the Outside World on Fais Island in Micronesia: 1994 Research*. Preliminary Report submitted to the Historic Preservation Office, Yap State, Federated States of Micronesia.
- Intoh, M. 1996a. Multi-regional contacts of prehistoric Fais Islanders in Micronesia. *Bulletin of the Indo-Pacific Prehistory Association* 15:111-117.
- Intoh, M. 1996b. Analyses of glass artefacts excavated from the prehistoric cemetery of Fais Island. *Research Reports of Composite Research Unit of Tokai University* 20:241-245 (in Japanese).
- Intoh, M. 1997. Human dispersals into Micronesia. *Anthropological Science* 105(1):15-28.
- Intoh, M. 2000. Inter-island exchange systems in Oceania. In *Archaeology of Exchange* (H. Ogawa, ed.):50-72. Tokyo: Asakura Shoten (in Japanese).
- Intoh, M. 2008. Ongoing archaeological research on Fais Island, Micronesia. *Asian Perspectives* 47(1):121-138.
- Intoh, M. and W. R. Dickinson. 2002. Prehistoric pottery movements in western Micronesia: technological and petrological study of potsherds from Fais island. In *Fifty Years in the Field: Essays in Honour and Celebration of Richard Shuttler, Jr.'s Archaeological Career* (S. Bedford, D. Burley, and C. Sand, eds.):123-134. Wellington: New Zealand Archaeological Association Monograph 25.
- Intoh, M. and R. Ono. 2006. Reconnaissance archaeological research on Tobi Island, Hatohobei State, Palau. *People and Culture in Oceania* 22:53-82.
- Intoh, M. and R. Ono. n.d. *Archaeological Research on Fais Island, 2005 Field Season*. Manuscript of report to be submitted to the HPO of Yap State, FSM.
- Intoh, M. and N. Shigehara. 2003. Prehistoric pig and dog remains from Fais Island, Micronesia. *Anthropological Science* 112:257-267.
- Johannes, R. E. 1981. *Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia*. Berkeley: University of California Press.
- Kaneko, S. and K. Saito. 1980. *Morphology of Shark Vertebrae and Its Possibility as Age Determination*. B.A. Thesis. Shimizu: Tokai University Kirch, P.V. 1988. *Niuatoputapu: The Prehistory of a Polynesian Chieftdom*. Seattle: Burke.
- Kirch, P. V. 1988. *Niuatoputapu: The Prehistory of a Polynesian Chieftdom*. Seattle: Burke.
- Kirch, P. V. 1989. *The Evolution of the Polynesian Chieftdoms*. Cambridge: Cambridge University Press.

- Kirch, P. V. and T. S. Dye. 1979. Ethnoarchaeology and the development of Polynesian fishing strategies. *Journal of Polynesian Society* 88:53-76.
- Kirch, P. V. and D. E. Yen. 1982. *Tikopia; The Prehistory and Ecology of a Polynesian Outlier*. Honolulu: B.P. Bishop Museum Bulletin 238.
- Lamb, H. H. 1995. *Climate History and the Modern World*. (2nd ed) London: Routledge.
- Leach, B. F. 1986. A method for analysis of Pacific island fishbone assemblages and an associated data base management system. *Journal of Archaeological Science* 13(2):147-159.
- Leach, B. F. 2006. *Fishing in Pre-European New Zealand*. Wellington: New Zealand Journal of Archaeology.
- Leach, B. F. and J. M. Davidson. 1977. Fishing methods and seasonality at Paremata (N160/50). *New Zealand Archaeological Association Newsletter* 20(3):166-175.
- Leach, B. F. and J. M. Davidson. 1988. The quest for the rainbow runner: Prehistoric fishing on Kapingamarangi and Nukuoro Atolls, Micronesia. *Micronesica* 21:1-22.
- Leach, B. F. and J. M. Davidson. 2006a. *Analysis of Faunal Material from an Archaeological Site Complex at Mangilao, Guam*. Wellington: Museum of New Zealand Te Papa Tongarewa, Technical Report 38.
- Leach, B. F. and J. M. Davidson. 2006b. *Analysis of Faunal Material from an Archaeological Site at Ylig, Guam*. Wellington: Museum of New Zealand Te Papa Tongarewa, Technical Report 39.
- Leach, B. F., J. M. Davidson, and J. S. Athens. 1996. Mass harvesting of fish in the waterways of Nan Madol, Pohnpei, Micronesia. In *Oceanic Culture History: Essays in Honour of Roger Green* (J. M. Davidson, G. Irwin, B. F. Leach, A. Pawley, and D. Brown, eds.):319-341. Wellington: New Zealand Journal of Archaeology Special Publication.
- Leach, B. F., J. M. Davidson, and M. Horwood. 1994. *Analysis of Fish Bone from Five Archaeological Sites on Fais, Caroline Islands*. Unpublished manuscript. Wellington: Museum of New Zealand Te Papa Tongarewa Technical Report 4.
- Leach, B. F., J. M. Davidson, M. Horwood, and P. Ottino. 1997. The fishermen of Anapua Rock Shelter, Ua Pou, Marquesas Islands. *Asian Perspectives* 36(1):51-66.
- Leach, B. F., J. M. Davidson, G. K. Ward, and J. Craib. 1988. Prehistoric fishing at Mochong, Rota, Mariana Island. *Man and Culture in Oceania* 4:31-62.
- Leach, B. F., M. Intoh, and J. Chazine. 1984a. An archaeological fishbone assemblage from the Vitaria site, Rurutu, Austral Islands. *Journal de la Société des Océanistes* 78:75-77.
- Leach, B. F., M. Intoh, and I. W. G. Smith. 1984b. Fishing, turtle hunting, and mammal exploitation at Fa'ahia, Huhahine, French Polynesia. *Journal de la Société des Océanistes* 79:183-197.
- Lehodey P. 2001. The pelagic ecosystem of the tropical Pacific Ocean: Dynamic spatial modelling and biological consequences of ENSO. *Progress in Oceanography* 49:439-468.
- Lehodey P., M. Bertignac, J. Hampton, and A. Lewis. 1997. Picaut J. El Niño southern oscillation and tuna in the western Pacific. *Nature* 389:715-718.
- Lehodey P., F. Chai, and J. Hampton. 2003. Modelling climate-related variability of tuna populations from a couple ocean-biogeochemical-populations dynamics model. *Fisheries Oceanography* 12(4):483-494.
- Marsac, F. and J. L. Le Blanc. 1998. Dynamics of ENSO events in the Indian Ocean: To what extent would recruitment and catchability of tropical tunas be affected? *Proceedings of the 7th Expert Consultation on Indian Ocean Tunas*: 89-101. Victoria: Seychelles.
- Masse, W. B. 1986. A millennium of fishing in the Palau Islands, Micronesia. In *Traditional Fishing in the Pacific: Ethnographic and Archaeological papers from the 15th Pacific science congress* (A. Anderson, eds.):85-117.
- Masse, W. B. 1989. *The Archaeology and Ecology of Fishing in the Belau Islands, Micronesia, Part 1 and Part 2*. Ann Arbor: University Microfilms.
- Masse, W. B., J. Liston, J. Carucci, and J. Athens. 2006. Evaluating the effects of climate change on environment, resource depletion, and culture in the Palau Islands between AD 1200 and 1600. *Quaternary International* 151:106-132.
- McAlister, A. J. 2002. *Prehistoric Fishing at Fakaofu, Tokelau: A Case of Resource Depression on a Small Atoll*. M.A. Thesis. Auckland: University of Auckland.
- Miller, K. A. 2007. Climate variability and tropical tuna: Management challenges for highly migratory fish stocks. *Marine Policy* 31:56-70.
- Moy, C. M., G. O. Seltzer, D. T. Rodbell, and D. M. Anderson. 2002a. Variability of El Niño/Southern Oscillation activity at millennial timescales during the Holocene epoch. *Nature* 420:162-165.

- Moy, C. M., G. O. Seltzer, D. T. Rodbell, and D. M. Anderson. 2002b. *Laguna Pallcacocha Sediment Color Intensity Data IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series #2002-76*. Boulder: NOAA/NCDC Paleoclimatology Program.
- Nason, J. D. 1975. The effects of social change on marine technology in a Pacific atoll community. In *Maritime Adaptations of the Pacific* (R. W. Casteel and G. I. Quimby, eds.):5-38. The Hague: Mouton Publisher.
- Nunn, P. D. 1999. *Environmental Change in the Pacific Basin: Chronologies, Causes, Consequences*. London: Wiley.
- Nunn, P. D. 2000a. Environmental catastrophe in the Pacific Islands around AD 1300. *Geoarchaeology* 15:715-740.
- Nunn, P. D. 2000b. Illuminating sea-level fall around AD 1220-1510 (730-440 cal yr BP) in the Pacific Islands: Implications for environmental change and cultural transformation. *New Zealand Geographer* 56:4-12.
- Nunn, P. D. 2003. Revising ideas about environmental determinism: Human-environment relations in the Pacific Islands. *Asia Pacific Viewpoint* 44:63-72.
- Nunn, P. D. 2007. *Climate, Environment and Society in the Pacific During the Last Millennium*. Amsterdam: Elsevier.
- Nunn, P. D., R. Hunter-Anderson, M. T. Carson, F. Thomas, S. Ulm, S., and M. J. Rowland. 2007. Times of plenty, times of less: Last-millennium societal disruption in the Pacific. *Human Ecology* 35:385-401.
- O'Connell, J. F. 1972. *A Residence of Eleven Years in New Holland and the Caroline Islands* (edited by S. H. Reisenberg, ed.). Canberra: The Australian National University Press.
- Ono, R. 2003. Prehistoric Austronesian fishing strategies: A tentative comparison between Island Southeast Asia and Lapita Cultural Complex. In *Pacific Archaeology: Assessments and Prospects* (C. Sand, ed.):191-201. Noumea: New Caledonia Museum.
- Ono, R. 2004. Prehistoric fishing at Bukit Tengkorak rock shelter, east coast of Borneo Island. *New Zealand Journal of Archaeology* 24:77-106.
- Ono, R. 2006. *Marine Exploitation and Subsistent Strategies in Celebes Sea: An Ethnoarchaeological Studies to Area Studies*. Ph.D. Thesis. Tokyo: University of Sophia (in Japanese).
- Ono, R. 2007. "Tradition" and "modernity" in fishing among the Sama, Eastern coast of Borneo, Malaysia. *Bulletin of the National Museum of Ethnology* 31(4):497-579 (in Japanese).
- Ono, R. 2008. Human history of shark exploitations in the Pacific and Asia. *Magazine of Biological Science* 62(3):72-75 (in Japanese).
- Ono, R. 2009. Ethno-Archaeology in coral seas. *Quarterly of Archaeological Studies* 55(4):175-194 (in Japanese).
- Ono, R. 2010. Ethno-Archaeology and the early Austronesian fishing strategies in inshore environments. *Journal of the Polynesian Society* 119(3):269-314.
- Ono, R. and D. Addison. 2009. Ethno-Ecology and Tokelauan fishing lore from Atafu atoll, Tokelau. *SPC Traditional Marine Resource Management Knowledge Information Bulletin* 26:3-22.
- Ono, R. and G. Clark. n.d. A 2500-year record of marine resource use on Ulong Island, republic of Palau. *International Journal of Osteoarchaeology*. Revised paper submitted for publication.
- Reitz, E. J., I. R. Quitmyer, and R. A. Marrinan. 2009. What are we measuring in the zooarchaeological record of prehispanic fishing strategies in the Georgia Bight, USA? *Journal of Island and Coastal Archaeology* 4(1):2-36.
- Reitz, E. J. and E. S. Wing 2008. *Zooarchaeology*, 2nd ed. Cambridge: Cambridge University Press.
- Rick, T. C., J. M. Erlandson, M. A. Glassow, and M. L. Moss. 2002. Evaluating the economic significance of sharks, skates, and rays (Elasmobranchs) in prehistoric economies. *Journal of Archaeological Science* 29:111-122.
- Rolett, B. 1989. *Hanamiiai: Changing Subsistence and Ecology in the Prehistory of Tabuata, Marquesas Islands, French Polynesia*. Ann Arbor: University Microfilms.
- Ruhen, O. 1986. Where sharks are gods. In *Sharks: Silent Hunters of the Deep (Reader's Digest, ed.):106-111*. Sydney: Reader's Digest Services Pty Ltd.
- Seymour, K. L. 2004. Empirical data for archaeological fish weights analysis. In *Maya Zooarchaeology* (K. Emery, ed.):159-173. Los Angeles: Costen Institute of Archaeology Monograph 51.
- Springer, V. G. and J. A. F. Garrick. 1964. A survey of vertebral numbers in sharks. *Proceedings of the United States National Museum* 116:73-96.
- Steadman, D. W. and M. Intoh. 1994. Biogeography and prehistoric exploitation of birds from Fais Island, Yap State, Federated States of Micronesia. *Pacific Science* 48(2):116-135.
- Stequert, B. and F. Marsac. 1989. *Tropical Tuna: Surface Fisheries in the Indian Ocean*. FAO Fisheries Technical Paper 282. Rome: FAO.

- Stuiver, M., P. J. R. E. Bard, J. W. Beck, G. S. Burr, K. A. Hughen, B. Kromer, G. McCormac, J. V. D. Plicht, and M. Spurk. 1998. INTCAL98 radiocarbon age calibration, 24000-0 cal BP. *Radiocarbon* 40(3):1041-1083.
- Suarez-Sanchez J., W. Ritter-Ortiz, C. Gay-Garcia, and J. Torres-Jacome. 2004. ENSÖ-tuna relations in the eastern Pacific Ocean and its prediction as a non-linear dynamic system. *Atmosfera* 17(4):245-258.
- Thompson, L. G. and E. Mosley-Thompson. 1987. Evidence of abrupt climatic change during the last 1500 years recorded in ice cores from tropical Quelccaya ice cap, Peru. In *Abrupt Climatic Change* (W. H. Berger and L. D. Labeyrie, eds.):99-110. Dordrecht: Reidel.
- Toizumi, T. 2007. Analytical problems with identification of fish remains in prehistoric Ryukyu. In *Archaeological Studies on Cultural Diversity in Southeast Asia and its Neighbors* (M. Marui, ed.):307-320. Tokyo: Yuzankaku Press (in Japanese).
- Vaea, H. and W. Straatmans. 1954. Preliminary report in a fishing in Tonga. *Journal of Polynesian Society* 63:199-215.
- Vogel, Y. 2005. *Ika*. M.A. Thesis. Dunedin: University of Otago.