Fishing for tuna in Pacific prehistory.

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Abstract

The archaeological evidence from faunal analyses in the Pacific suggests an emphasis on inshore fish and fishing strategies. In contrast, the faunal evidence for offshore fish such as tuna is slight. Several sites in East Polynesia with high proportions of tuna are unusual in this regard. Yet ethnographic accounts of fishing in the Pacific region often contain detailed descriptions of offshore fishing expeditions to catch pelagic fish, including tuna. These fish continue to occupy a significant place in the cultural life of many Pacific island communities.

The uneven representation of tuna in archaeological sites is not thought to derive from any known taphonomic process, but fairly represents the relative abundance of tuna in catches through-out the Pacific. Discontinuities in catch frequency do not follow any known variations in natural abundance, and the preferred explanation is cultural choice. Moreover, in sites were tuna were a major component of the catch, there appears to be a small but consistent decline in their relative abundance, once again believed to reflect culture-historical rather than natural processes. The ethnographic and archaeological evidence is reviewed for several areas in the Pacific where tuna were more commonly caught. The evidence from faunal analyses is considered for four archaeological sites, Hane and Te Anapua in the Marquesas Islands, Fa`ahia in the Society Islands and Motupore in Papua New Guinea, where tuna were caught in relatively high abundance. Techniques are described for reconstructing size-frequency information from archaeological bones form these sites. It is argued that the social importance as well as economic aspects of tuna fishing need to be incorporated in explanations for the presence of tuna in archaeological sites.

Preface

The central theme of this thesis, tuna fishing in Pacific prehistory, arose during the analysis of the Hane fish bone collection, which was excavated by Dr Y.H. Sinoto, and subsequently analysed at the Archaeozoology Laboratory, Museum of New Zealand. Accordingly I would like to thank Dr Sinoto, the Bishop Museum and the Archaeozoology Laboratory, Museum of New Zealand for the opportunity to study this material. I would also like to thank the Skinner Fund, Royal Society of New Zealand for their support of the Hane project.

I gratefully acknowledge Foss Leach and Richard Walter's supervision of this thesis. My thanks also to Foss, and the Archaeozoology Laboratory, Museum of New Zealand, for access to the accumulated database of Pacific island fish bone identifications and the collections themselves.

I would also like to thank Janet Davidson for her valuable assistance.

Table of Contents

List of Tables

(short captions)

List of Figures

(short captions)

1: Introduction

Marine resources have played an important role in many parts of the Pacific throughout prehistory. Present evidence favours the emergence of a maritime based economy by at least 35,000 years ago on the islands to the north and east of mainland Papua New Guinea, such as New Ireland and Buka. Archaeological sites on these islands show clear evidence of inshore fishing activities well back into the Pleistocene (Allen *et al.* 1989, Allen and Gosden 1966, White *et al.* 1991, Marshall and Allen 1991, Wickler and Spriggs 1988).

Most studies of fishing in the Pacific until recently were ethnographic in focus, rather than archaeological. An exception to this was Gifford's early work describing fish remains from archaeological sites on Fiji (Fowler 1955), followed by Reinman's work *Fishing: An aspect of Oceanic economy* (1967). This work attempted to synthesise the disparate sources of information on fishing, including the small amount of data from archaeological investigations. It is hardly surprising that Reinman was forced to draw most of his information from ethnological and ethnographic sources.

Historically, archaeologists in the Pacific region have focused primarily on the fishing gear found in sites as a means of constructing cultural sequences. Variations in fish-hook styles have been used as chronological markers and to trace cultural relationships (for example Emory *et al.* 1959, Golson 1959, Sinoto 1968). Several studies have also considered technological aspects of fish-hooks. Reinman (1970) looked at the marine environment in conjunction with structural and functional variations in fish-hook technology, and considered the fish-hook as an adaptive device used to exploit particular marine environments. Allen (1996) and Goto (1986) have considered stylistic and functional variation in fish-hooks, while Davidson and Leach (1996) considered different approaches to the classification of fish-hooks, and the relationship between form and function.

Only in the last twenty years has the analysis of faunal remains recovered from sites formed an important component of investigations in the Pacific. Changing patterns of marine resource use are apparent in many studies. Variations in fish and shellfish sizes have been demonstrated in New Zealand (Anderson 1979, Swadling 1972), and the Pacific (Best 1984, Swadling 1986, Spennemann 1987). Changing relative abundances of fish have been documented from New

Zealand (Leach and Boocock 1993), and the Pacific (Allen 1992, Dye 1990, Leach and Davidson 1988, Leach and Ward 1981, Rolett 1989). Variations in the relative frequency of turtle remains in sites have also been demonstrated (Kirch and Dye 1979, Kirch and Yen 1982).

The increasing use of faunal data sets in Pacific archaeology has been accompanied by the development of a body of work which critically examines the implications of the methodological and analytical techniques used. The study of fish remains involves many issues such as sampling, identification, quantification and taphonomy that are common to the analysis of all faunal data (see Grayson 1984, Lyman 1994, Ringrose 1993). Aspects of recovery and quantification in particular have been considered from a Pacific perspective (for example Butler 1988, 1994, Dye 1996, Nagaoka 1993, 1994).

Several broad themes can be recognised in the archaeological study of marine resource use in the Pacific: ecologically oriented studies, subsistence economics, and the study of fishing practices.

Ecological approaches are concerned with the role the environment plays in shaping human behaviour and the corresponding effects that people have on their environment. Kirch (1982) investigated how the diverse marine environments in the Hawaiian islands contributed to the development of fishing strategies. Studies of the different marine resources used by the Lapita people have been concerned with the identification of species in relation to the exploitation of particular ecological zones (Swadling 1986, Lepofsky 1988). Decreases in shell size and changes in abundance of shellfish in sites have been attributed to the impact of people on these resources (Best 1984, Leach and Anderson 1979, Swadling 1986, Spennemann 1987). Several reasons have been suggested for an increase in the size of snapper at Rotokura, including seasonal occupation effects, natural environmental changes, and localised depletion (Leach and Boocock 1995). The impact of people on pristine resources, and the process of colonisation of previously uninhabited islands has also been investigated (Anderson *et al.* 1996, Kirch 1973, Kirch and Yen 1982, Leach and Ward 1981, Leach *et al.* 1984, Rolett 1989).

Studies of subsistence economics are specifically concerned with how groups of people have met their basic nutritional requirements. The first serious attempt made in New Zealand to evaluate the quantitative role of different food ingredients in ancient diets was by Shawcross in a series of publications in which he worked out relative abundance of various species using MNI, and carried out experimental and literature research to assess the usable meat weight, caloric value and vitamin content of the different components (Shawcross 1967a, 1967b, 1972, 1975). He used this as a basis for a quantitative perspective of what the meat part of early Maori diets must have been like. More recently, techniques have been developed to estimate the contribution by meat weight of particular components of the diet in parts of New Zealand; notable amongst these have been works by Anderson (1973), Sutton (1979, 1980, 1989), and Smith (1985). A method for estimating the live lengths and weights of fish catches from archaeological bones of particular species has also been developed (Leach and Boocock 1995, Leach *et al.* 1996b, Leach *et al.* 1996c, Leach *et al.* 1997a, Leach *et al.* 1997c). The contributions of various components of the diet, including marine resources, have been determined from stable isotope ratios in human bone (Quinn 1989, Leach, Quinn *et al.* 1996). The overall importance of fishing and shellfish have also been considered in relation to other subsistence activities in various parts of the Pacific (Kirch and Dye 1979, Kirch and Yen 1982, Dye 1990).

Another theme in the archaeological investigation of marine resource use in the Pacific centers around the study of fishing.[1] Questions relating to human behaviour associated with fishing have generally been considered in terms of fishing strategies. The fishing strategies which ultimately result in the deposition of fish remains in sites involve economic, ecological, technological and cultural aspects, that are to a major degree interrelated.

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[1] The issue of gender specific terms constantly arises during discussions about fishing. One approach is simply to use the term 'fisher' every time one might, in the past, have used the term 'fisherman'. I believe this option does not do justice to the potential richness of archaeological interpretation. In this thesis, I have followed the procedure of using gender inclusive terms such as 'people who fished', 'fisher-folk', etc. when I intend to convey the meaning that men, women, and children were likely to have been involved in the fishing activity being discussed. When I believe that the dominant gender for a particular activity were males, I use the term 'fisherman(men)'. When females were probably the dominant gender involved, I use the term 'fisherwoman(women)'. At the outset, the point must be made (and this is discussed in detail at several parts of this thesis), that many lines of evidence point to the fact that tuna fishing in the Pacific was for all practical purposes the exclusive domain of men. Since this thesis is primarily concerned with tuna fishing, the term 'fisherman/men' will occur frequently.

The identification and quantification of fish remains in sites have been used to reconstruct fishing strategies, often in association with ethnographic evidence about fishing methods, and knowledge of fish behaviour (for example Kirch and Dye 1979, Leach *et al.* 1988, Masse 1982, 1986, Walter 1991). Recent developments in Pacific archaeology have seen archaeologists undertake their own research in contemporary societies to better understand aspects of human behaviour which result in the formation of the archaeological record. This kind of ethnoarchaeological research has been carried out for fishing in several areas in the Pacific (see Dye 1983, Walter 1991, Kirch and Dye 1979, Marshall 1987, Rolett 1989).

Aspects of temporal variability in fishing practices, and the articulation of fishing strategies with other cultural and environmental processes have also been investigated. Cultural prohibitions and avoidance behaviour have been suggested as a factor which has shaped the composition of fish bone assemblages from some islands in the Pacific (Kirch and Yen 1982, Leach *et al.* 1996a, Leach and Davidson 1988, Leach *et al.* 1988). Changes in fishing gear in the Marquesas have been interpreted by Kirch (1980) as a response to different environmental conditions faced by colonists. Dye (1990) argues that these changes were not adaptive, but rather maladaptive. He attributes a decline in offshore fishing in the Marquesas to cultural variables, particularly the development of a class system with unequal access to fishing technology and resources. He also argues that purely ecological interpretations are insufficient to explain aspects of change in Polynesia. Allen (1992) examined spatial and temporal trends in shell fish-hook technology and related patterns of fish capture in the Cook Islands, in terms of the availability of resources and environmental factors. She also considered the implications of the changing social context; including labour requirements, the costs and benefits of angling compared to other techniques, and the relationship between fishing and other subsistence activities. Archaeological investigations at Shag River Mouth, southern New Zealand, were concerned with attempting to understand how the settlement of a cool-temperate environment, by Polynesian peoples from a subtropical climate, resulted in changes to the subsistence economy, and also settlement patterns (Anderson, Allingham and Smith 1996). The effect of human settlement in a previously pristine environment was also considered.

Apparent in many of the archaeological studies of fishing in the Pacific is the high relative abundance of inshore fish, and the emphasis on inshore fishing strategies (Butler 1988, Dye 1983, Green 1986, Kirch and Dye 1979, Fleming 1986, Masse 1986, Nagaoka 1993). Conversely, the archaeological evidence for offshore fishing is slight. Sites such as Fa`ahia in the Society Islands, French Polynesia, which contain large numbers of offshore fish and marine animals, have been considered highly unusual in this regard (Leach *at al.* 1984). However, recent analyses of material from sites in the Marquesas (Davidson, Fraser *et al* n.d., Leach *et al.* 1997b, Rolett 1989) and Mochong (Leach *et al.* 1988) have revealed that other groups of people were also successfully engaged in fishing for offshore species.

The relatively minor role that offshore fishing strategies seem to have played in many prehistoric Pacific islands, based on the paucity of offshore fish remains in archaeological sites, contrasts with the amount of attention focused on this activity by ethnographers. Early ethnographic accounts often include detailed commentary on offshore fishing expeditions and the fishing gear used to catch pelagic fish, particularly tuna (for example Buck 1930, Burrows 1936, 1937, Kennedy 1930). Tuna fishing also continues to occupy an important place in many Pacific island communities today (Dye 1983, Gillet 1985, 1987, Leach and Davidson 1988, Lieber 1994).

Explanations for the emphasis on inshore fish taxa include ecological and economic reasons. The proportions of fish in sites are seen as a reflection of the substantially greater biomass of coral reefs, as opposed to that of benthic and pelagic communities (Kirch and Yen 1982), or the fact that reef ecosystems are generally more diverse and have a higher productivity rate than open ocean environments (Nagaoka 1993). However, people do not necessarily catch fish in proportion to their relative abundance in nature. The low contributions made by offshore fish such as tuna towards subsistence has also been suggested to relate to issues of return for effort.

The variability of offshore fish remains in archaeological sites and the apparent contrast with the importance of offshore fish in ethnographic literature have prompted this present study. The focus of the research is on tuna and tuna fishing, and the study aims to contribute to a better understanding of the role of offshore fishing in Pacific prehistory. The principal focus is on the archaeological remains of tuna from Pacific island sites. The assemblages of fish bone used in this research form part of the accumulated database of Pacific Island fishbone identifications at the Museum of New Zealand's Archaeozoology Laboratory. Information about the ecology of tuna, in conjunction with a review of historic accounts of tuna fishing and its social and economic role is used to aid in the interpretation of the archaeological evidence.

Chapter 2 provides background information about the biology and behaviour of tuna. There is an emphasis on areas such as feeding behaviour and distribution, and also osteology, as these are particularly relevant to this study. The archaeological implications of this information are then discussed, and an overview of tuna remains in Pacific archaeological sites given.

Chapter 3 identifies the main methods and strategies used to catch tuna, from historical and contemporary sources. The archaeological visibility of these methods and strategies is considered.

Chapter 4 evaluates the usefulness of ethnographic literature in investigating aspects of tuna fishing. Possible social and cultural correlates of tuna fishing activities identified from these sources are then discussed.

Chapter 5 presents information from several sites in the Pacific where tuna remains are present in high proportions. A range of data is considered, including relative abundances and species present. The character of fishing in these sites is compared with other Pacific fishbone assemblages.

Chapter 6 investigates the dietary contribution made by tuna in the sites previously discussed. The possibility that tuna and other pelagic fish provide a better return for effort expended than inshore species is considered. A method for the reconstruction of live fish length and weight from archaeological bone measurements is outlined, and the results of its application to these sites is presented and discussed.

Chapter 7 evaluates the results in terms of what they can tell us about tuna fishing during the prehistoric period in the Pacific region.

2: The Scombridae family: ecology and archaeological implications

The Scombridae family is a member of the sub-order Scombroidei of the order Perciformes. This sub-order consists of the tunas and tuna-like species, including billfish, swordfish and other related species (Collette and Nauen 1983). These fish are characteristically fast swimming predators inhabiting pelagic waters, some of which attain large body size. This chapter outlines ecological information about the Scombridae family, considers some of the implications in terms of archaeological investigation, then introduces the archaeological fishbone assemblages which are the focus of this study.

Ecology

Taxonomy

The Scombridae family is composed of 15 genera comprising 49 species of mostly epipelagic marine fishes: the mackerels, Spanish mackerels, bonitos and tunas (Collette and Nauen 1983, Nelson 1994) (Figure 1). The family is further divided into two sub-families: the Gasterochismatinae, which contains the single species *Gasterochisma melampus*, and the Scombrinae. The Scombrinae have been divided into four groups of tribes, on the basis of internal osteological characteristics. These tribes are the primitive mackerels and Spanish mackerels, and the more advanced bonitos and tunas.

Members of the Scombridae family are differentiated by physiological features, including osteological characteristics (Figure 2). The mackerels (Scombrini) and Spanish mackerels (Scomberomorini) are characterised by:

(i) a distinct notch in the hypural plate that supports the caudal fin rays,
(ii) the lack of any bony support for the fleshy caudal peduncle keels, and
(iii) the caudal vertebrae centra not greatly shortened as compared to other vertebrae (Collette and Nauen 1983: 590).

The bonitos (tribe Sardini) consist of five genera of eight species (characterised by Collette and Chao 1975). They differ from the more primitive mackerels and Spanish mackerels in lacking a notch in the hypural plate, and in having a bony lateral keel on the posterior caudal vertebrae.

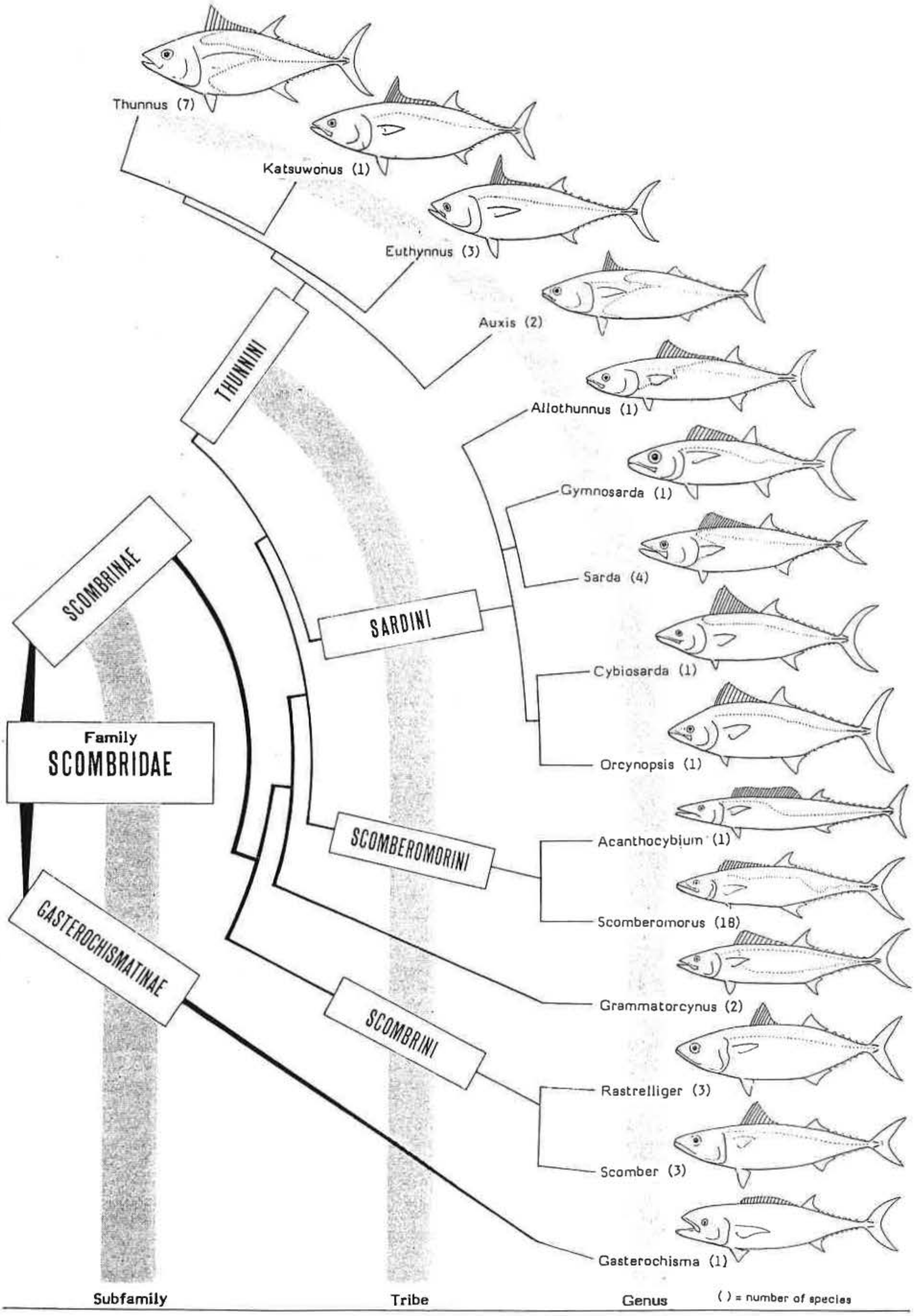
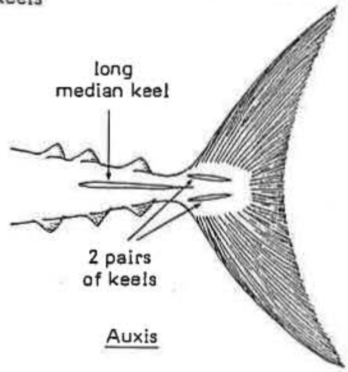
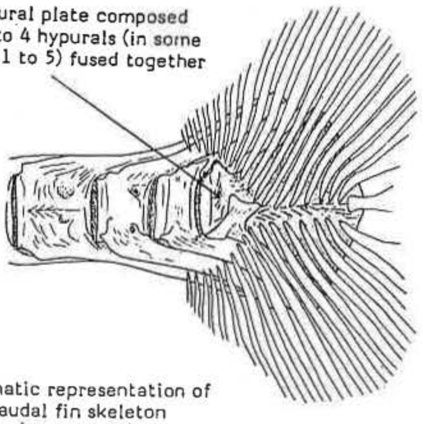


Figure 1: Classification of the Scombridae family (from Collette and Nauen 1983: 4).

Caudal keel - All members of the Scombridae have a pair of small obliquely oriented keels at the base of the caudal fin. The more advanced members of the family also have a large median keel on the middle of the caudal peduncle, anterior to the pair of small keels



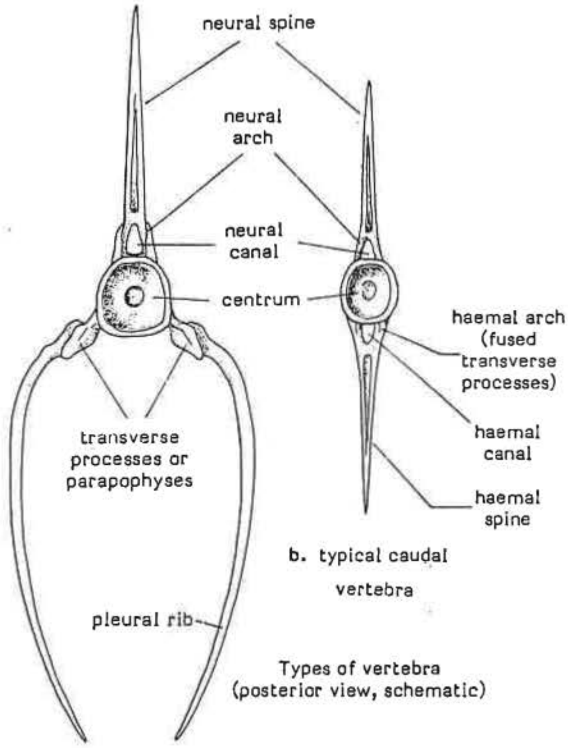
Hypural plate - The expanded ends of the hypural bones form a wide plate onto which the caudal fin rays insert. Scombrids differ from most other fishes in having the caudal fin rays so deeply divided that they completely cover the hypural plate.



Schematic representation of caudal fin skeleton (Orcynopsis)

Caudal vertebrae - Vertebrae that bear a haemal spine ventral to the vertebral centrum.

The first caudal vertebra is located near the origin of the anal fin. Caudal vertebrae lack pleural ribs which are characteristic of the precaudal vertebrae.



Types of vertebra (posterior view, schematic)

Caudal peduncle - The narrow part of the body just anterior to the caudal fin.

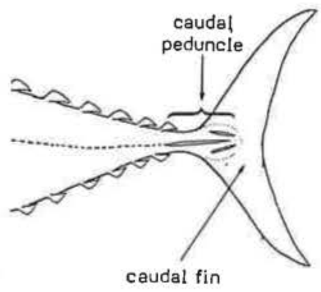


Figure 2: Illustrated glossary of physiological features of Scombridae tribes (from Collette and Nauen 1983: 6-9).

The bonitos differ from the higher tunas by having the bony keel only incompletely developed and lacking a specialised subcutaneous vascular system. The four genera of the Thunnini are unique among bony fishes in having a counter current heat exchanger system that allows them to retain metabolic heat so the fish is warmer than the surrounding water (Collette and Nauen 1983: 3).

The taxonomy and nomenclature used above are derived from *FAO Species Catalogue Vol. 2: Scombrids of the World* (Collette and Nauen 1983). Strictly speaking then, the term 'tuna' refers to only a small group of fishes within the Scombridae family. However, 'tuna' has come into common parlance to refer to various fishes in this family, distinguished from fishes like wahoo (*Acanthocybium solandri*). 'Tuna' most commonly refers to the two groups of fishes which Collette and Nauen (1983) and Nelson (1994) classify separately as 'tuna' and 'bonito'. These two tribes (Thunnini and Sardini) have very similar anatomy, and are therefore difficult to distinguish from archaeological bones. They are, however, distinguishable from other tribes. This issue will be discussed in more detail below. The identifications named in this thesis as Scombridae should be understood to refer to fishes in the tuna and bonito tribes. The common name tuna is also used for this group.

When considering references to tuna and tuna-like fishes in other literature it becomes apparent that the use of common names such as bonito cannot be considered as referring specifically to Linnean taxonomies. Some common names may be loosely applied to several species, or have changing usage. For example, Nordhoff's accounts of bonito fishing in the Society Islands (1930), describe surface trolling for fish which are now more commonly known as skipjack. Linnean taxonomies too are being constantly updated in the light of new information. The names of fishes in this family are also used as descriptors for members of other tribes within the same family. For example, kawakawa (*Euthynnus affinis*) is also known as the mackerel tuna, and the dogtooth tuna *(Gymnosarda unicolor*) is not classified by biologists as a tuna, but as a bonito (tribe Sardini).

Pacific islanders also have their own names and classificatory systems for the fish found in their waters. The resemblance between these systems and those of biologists is sometimes noted, however, the similarities are not as great as they appear (Johannes 1981: 124). The two-name Linnean system has two main purposes. Firstly, to designate the evolutionary origins of members of groups of closely related species, and secondly, to provide a naming system that is uniform throughout the international scientific community. By comparison, the functions of fish naming systems used by many Pacific island groups are somewhat different and their structures are more flexible. Many groups of fish are given a common generic name because of anatomical similarity. Others, which may be grouped together by biologists, are separated on the basis of appearance, habitat, feeding behaviour or capture method.

Linnean taxonomies are designed to encompass all known species, rare or common. Pacific island classificatory systems focus on those species which are important to Pacific islanders. In the case of tuna Pacific island systems are often more detailed than Linnean taxonomies, having specific names for tuna at different stages of their life cycle. In the Society Islands, Nordhoff (1930: 142) recorded several names for *ahi*, depending on their growth and character. He also suggests that fish given this name consisted of two species, the albacore and yellowfin tuna. This is probably a reflection of the catching method and similar habitat of these fish. Bonito (skipjack tuna) were also identified by growth stages (Nordhoff 1930: 247). Satawal tuna fishermen have more than one name for skipjack, yellowfin and bigeye depending on their life stage, while kawakawa, frigate and bullet tuna are referred to by one name, with no special name for each species (Gillet 1987: 19).

The classificatory systems used by Pacific islanders need to be considered in the cultural context in which they were formulated, as they are not limited to biological characteristics. For example, tuna and other ritually important fish on Satawal may also be given alternate names, as the use of ordinary names may be forbidden at particular times (Akimichi 1986). From an archaeological point of view, the binomial classificatory system used for fish remains will bear little relationship to that used by the original fishers, and this is a limitation in terms of learning about how people conceptualised their environment and responded to it. The binomial, common and some local names of Scombrids referred to in the text are given in Appendix 1.

Biology and behaviour

Members of the Scombridae family can be distinguished from other fishes on the basis of their tail structure (Collette and Chao 1975: 578, Gosline and Brock 1960: 253). The bases of the caudal rays completely overlap and conceal the caudal skeleton (Figure 3). In other fishes these rays only articulate with or partly cover the caudal skeleton. Therefore, in Scombrids the end of the vertebral column and the tail form a single, nearly inflexible unit, as opposed to a hinged

Figure 3: Caudal skeleton with the bases of the caudal fin rays covering the hypural plate (*Orcynopsis unicolor*) (from Collette and Chao 1975: 580).

junction. This facilitates the powerful and prolonged swimming which is a characteristic of members of this family.

Scombrids share a number of physical characteristics (Figure 4). Body shape is cigar or torpedo-like, round bodied in cross section with a pointed snout, deep mid-section and tapering tail. The elongated and streamlined body shape is designed for speed, to facilitate the capture of prey or the avoidance of predators. Scombrids have two dorsal fins, the first of which folds down into a groove, and distinctive finlets behind the second dorsal and anal fins running to the tail. The tail is deeply forked and has one to three paired keels at its base. The scales are small and cycloid, in some species they are missing from large areas of the body. Many Scombrids have a corslet of densely packed scales on the front part of the body.

Scombrids are dioecious (separate sexes) and most display little or no sexual dimorphism in anatomy or body markings. However, the females of many species attain larger sizes than the males. Spawning occurs throughout the year in tropical and subtropical waters with species-specific seasonal peaks. The eggs are pelagic and hatch into planktonic larvae. Studies of juvenile tuna from stomach contents of predators show a widespread distribution throughout the tropical Pacific (Argue *et al.* 1983).

The majority of Scombrids are fast swimming predators in open waters, although some prefer inshore waters and are often found along coral reefs. The oceanic species feed primarily on other suitably sized fish, squid and crustaceans inhabiting the surface waters of the open sea. When near reefs, they also prey heavily on the larval and early juvenile stages of reef dwelling fish and crustaceans. If they swim past steep outer reef drop-offs or enter deep atoll lagoons they may also prey on adult reef fishes. Reef-associated species prey either on zooplankton or fishes which occupy the water above the reef (Myers 1989: 254). Skipjack in particular exhibit distinctive behaviours when feeding, such as foaming and jumping. Birds are often associated with Scombrid schools feeding in surface waters. The main predators of the smaller Scombrids are other carnivorous fish, especially larger Scombrids and billfish. Because of their size large adult Scombrids have few predators, these being mainly billfish, sharks, dolphins and toothed whales.

Scombrids are schooling fishes in surface and near-surface waters, tending to form mono- or multi-species schools of similar sized individuals. Schools may consist of hundreds of tonnes of

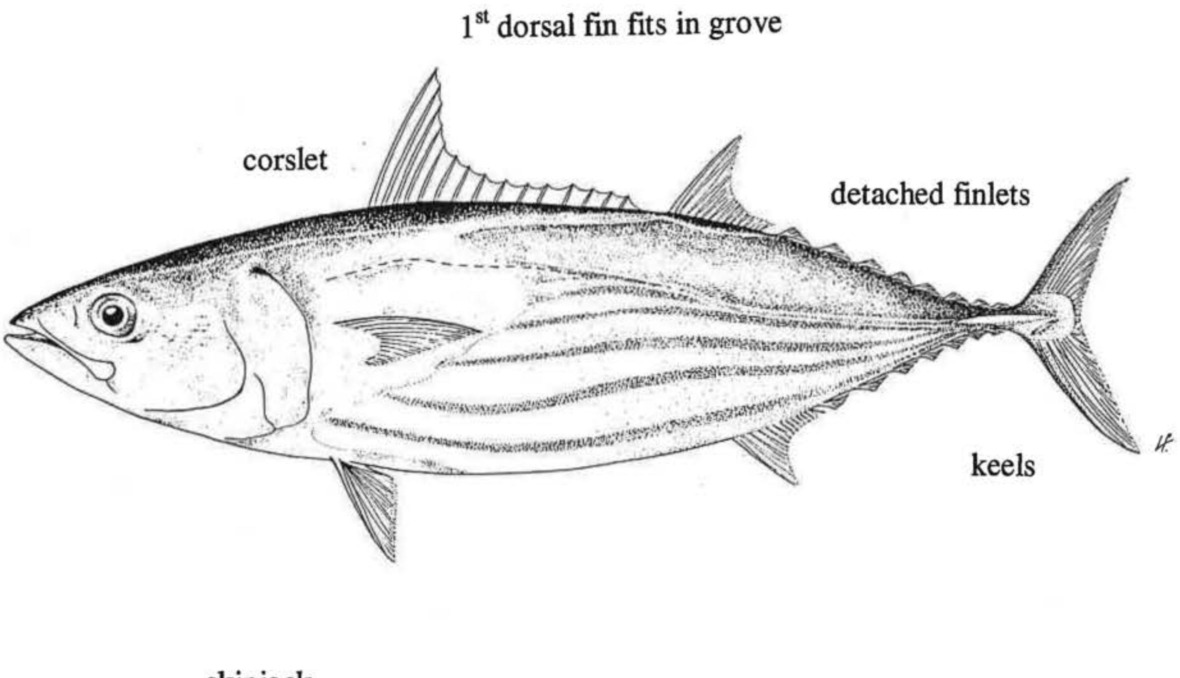


Figure 4: Physical characteristics of the Scombridae family.

fish which have a large commercial value in the world fisheries. Surface schools occur most often near islands, seamounts, thermal fronts, current interfaces and drifting logs (Gillet 1987: 15). Schools of small fish are chased up to the surface where they are preyed on from beneath. These schools are easily recognised by the birds which they attract, or by surface turbulence caused by the small fish leaping from the water and attempting to escape. The Spanish mackerels, particularly the wahoo, occur singularly or in small loose aggregations of fish rather than compact schools. The dogtooth tuna is also a solitary fish, usually occurring in groups of six or less. In surface waters tuna are often associated with floating logs and other naturally occurring debris. This has led to the development of both natural and artificial FADs (Fish Aggregation Devices) by commercial fisheries, however, little is known about the dynamics of tuna attraction to and retention at FADs (Shomura *et al.* 1994: 19). In the Eastern Pacific large yellowfin (greater than 85 cm fork length) frequently school with porpoises (Collette and Nauen 1983: 84).

Most fish have a body temperature close to that of the surrounding water, however, many tunas possess the unique ability to maintain body temperatures several degrees higher than the surrounding water. This is achieved through a vascular heat exchange system. The ability to regulate body temperature increases with size and is of particular importance to albacore, yellowfin and bigeye and best developed in bluefin (Collette and Nauen 1983). It also has implications for distribution, for example the bluefin tuna habitat ranges from their tropical breeding grounds with sea temperatures around 30°C, to feeding areas in the north Pacific where temperatures fall below 5°C. By comparison, although able to regulate its temperature, the yellowfin has a less well developed system and is more restricted in horizontal and vertical distribution.

Distribution

The following section is focused on those members of the Scombridae family by genus/species which commonly inhabit the pelagic waters of the Pacific ocean. Definitions of the terms used in this section will be outlined first. The marine environment can be divided initially into three habitats: open sea (pelagic), bottom (benthic) and reef or inshore (see Figure 5). The pelagic zone may be either neritic (water lying over the continental shelf) or oceanic (the rest of the ocean waters).The pelagic habitat is further subdivided into a series of depth zones. The epipelagic consists of warm surface isothermal waters, surface to 200m. Below this, in the

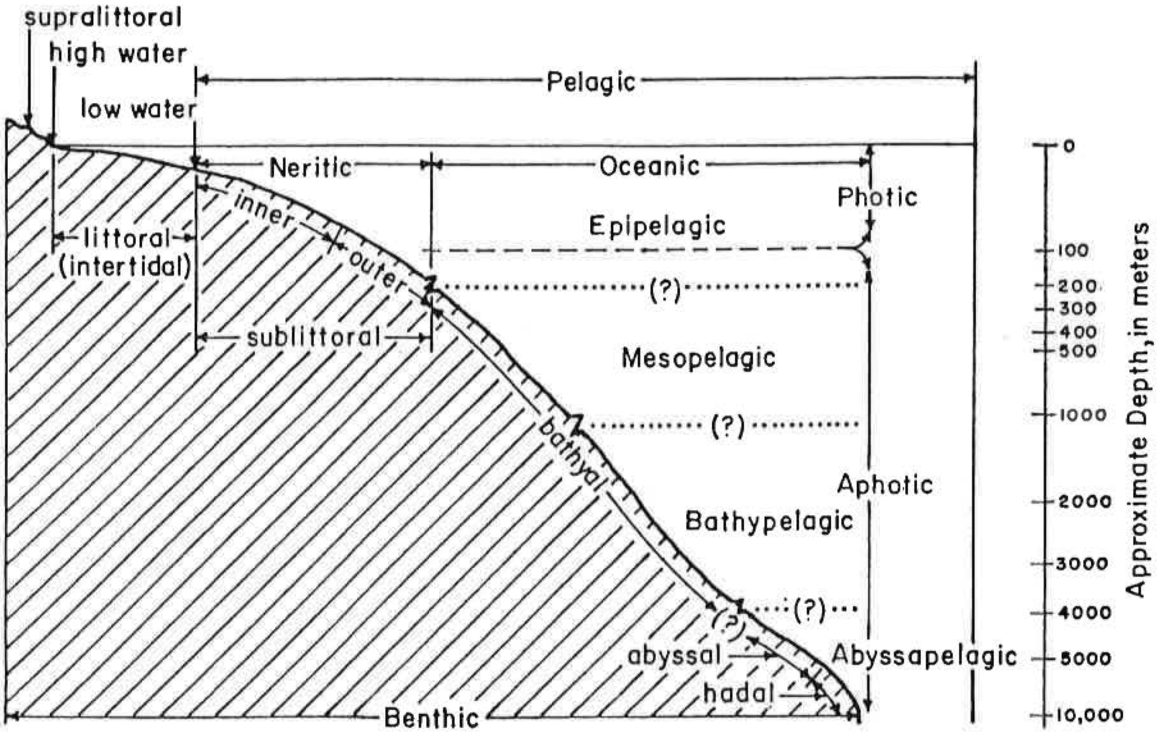


Figure 5: The marine environment (from Masse 1989: 113).

mesopelagic (200-100m) and other zones temperature falls rapidly with increasing depth. The thermocline comprises the interface of the warm surface waters and the cooler layers beneath.

Tuna (tribe Thunnini)

Several members of this tribe have an oceanic, global distribution which includes the waters of the Pacific (see Figure 6). They spend the juvenile stage of their life near the surface, and as they mature into adults (with the exception of skipjack) extend their range into greater depths. The vertical and horizontal distribution of tuna is dependant on food sources, proximity to shore, water temperature, oxygen content and other hydrological conditions, which vary between species.

Tuna are highly migratory, travelling between tropical spawning grounds and subtropical and temperate feeding grounds (Murray 1996: 55). Ethnohistoric and contemporary accounts of island fisheries in the Pacific invariably describe times of the year when tuna are more plentiful (for example Nordhoff 1930, Gillet 1987). Due to the increasing importance of tuna to the world's commercial fisheries numerous studies are being undertaken to establish the nature of tuna population, distribution and movements. However, as yet the dynamics of tuna migrations are not well understood. It has been suggested that "nomadic" is a better term than migratory to describe tuna movements (Stroud 1989). Although the movement of tuna into temperate waters is a seasonal phenomenon linked to water temperature, the routes taken can vary from year to year.

Yellowfin (*Thunnus albacares)* are one of the larger sized tunas, often having a 150 cm fork length, and sometimes reaching over 200 cm. They are an epipelagic, oceanic species found worldwide in tropical/subtropical seas. The thermal boundaries of their occurrence are roughly 18°C and 31°C. Their vertical distribution is influenced by the thermal structure and oxygen content of the water column. They are confined to the upper 100 m of water columns with marked vertical changes in oxygen content due to their minimum dissolved oxygen requirements. Yellowfin are caught as juveniles by commercial surface fisheries primarily using purse seines, and as adults from greater depths by long lining.

Albacore (*Thunnus alalunga*) are cosmopolitan in tropical and temperate waters of all oceans. Their range is between 45-50°N and 30-40°S, but they are not surface occurring between

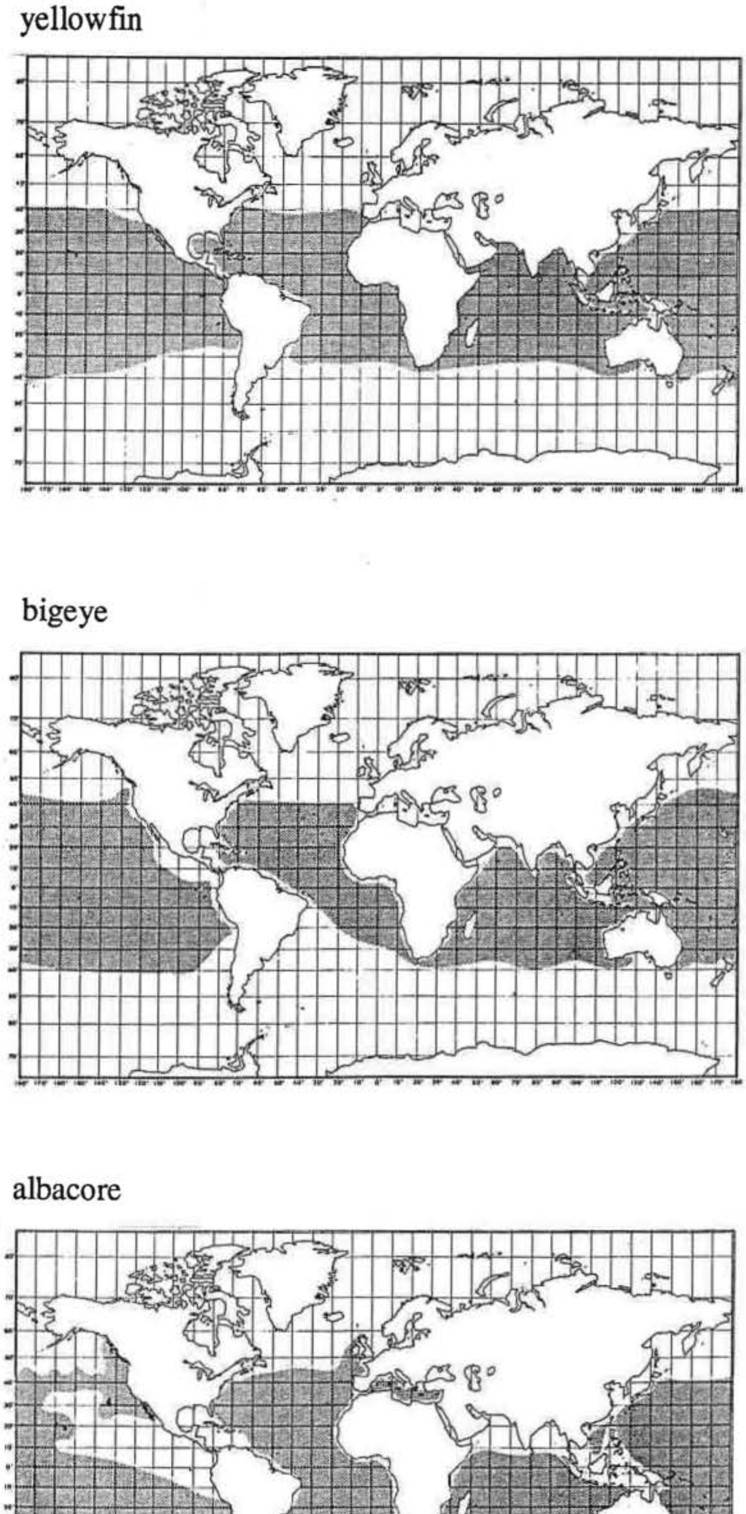
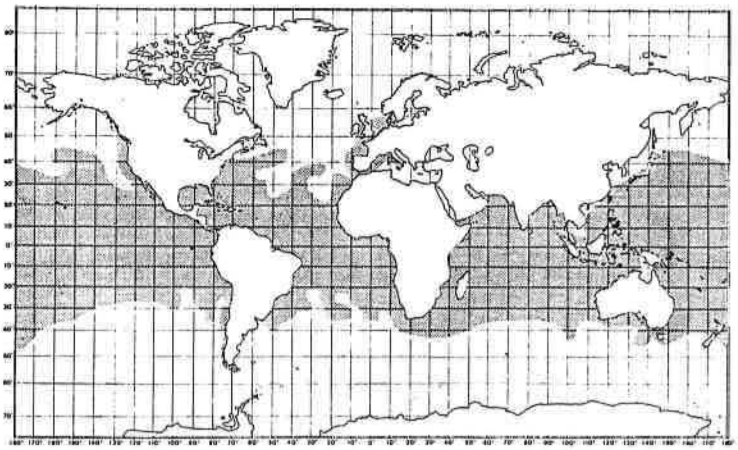


Figure 6: Distribution of members of the Thunnini tribe (yellowfin, bigeye, albacore) (from Collette and Nauen 1983).

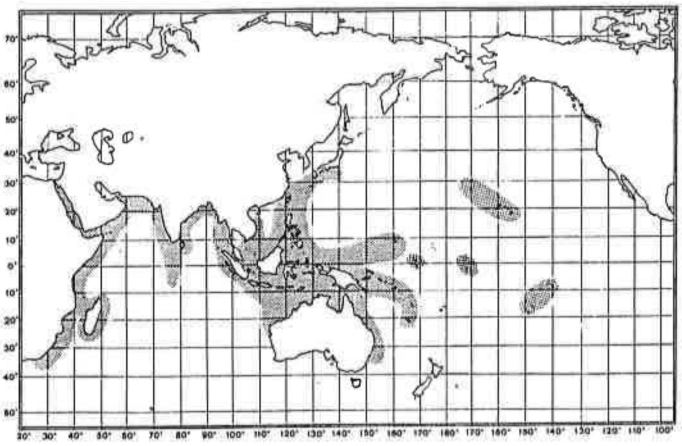
10°N and 10°S. They are epi- and meso-pelagic, oceanic fishes. Albacore are found in surface waters 15.6 to 19.4°C, while large, deeper swimming albacore are found from 13.5 to 25.2°C. In the Pacific, smaller sizes predominate in the catch of commercial surface fisheries (pole and line and trolling) (modes between 55 and 80 cm fork length), while the deeper long line fisheries are dominated by bigger fish (modes about 95 to 115 cm) (Collette and Nauen 1983: 82). Albacore tend to concentrate along thermal discontinuities including the Transition Zone, an oceanic front in the north Pacific. Their vertical range in the Pacific is from the surface to 380m, which is primarily governed by the thermal structure and oxygen content of the water. Albacore migrate within water masses rather than across temperature and oxygen boundaries.

Bigeye (*Thunnus obesus*) are one of the largest tunas, commonly reaching 180 cm fork length. They have a worldwide distribution in tropical/subtropical seas although they are absent from the Mediterranean. They are also epi- and meso-pelagic, oceanic fishes, found from the surface to about 250 m depth. The main conditions determining their distribution are temperature and thermocline depth. The temperature range in which bigeye occur is 13°C to 29°C, with an optimum range of 17°C to 22°C, which coincides with the temperature range of the permanent thermocline. Large concentrations of bigeye in the tropical central and western Pacific are associated with the thermocline, as opposed to the surface planktonic maximum, suggesting variation in distribution is closely related to seasonal and climactic changes in surface temperature and thermocline (Collette and Nauen 1983: 89).

Skipjack (*Katsuwonus pelamis*) are an epipelagic, oceanic species, cosmopolitan in tropical and warm-temperate waters, although absent from the Black Sea (Figure 7). Their distribution lies within the overall temperature range of 14.7 to 30°C. Skipjack are taken at the surface by commercial fisheries, usually by purse seines. They also form an important component of small scale local fisheries in the Pacific (Gillet and Toloa 1987). They commonly reach 80 cm in fork length. Aggregations tend to be associated with convergences, boundaries between cold and warm water masses (i.e. the polar front), upwelling and other hydrographical discontinuities (Shomura *et al.* 1994). Within the tropics, temperature may play only a minor role in determining small scale distribution, as the thermal gradients in these areas are generally weak. The frequent occurrence of skipjack in the vicinity of upwellings and convergences may result from the increased productivity associated with deep-origin, nutrient rich water and the concentration of drifting or weakly swimming biota. Similarly, increased skipjack abundance around islands, seamounts and banks may be a result of increased food supply near these areas skipjack



kawakawa



Auxis sp.

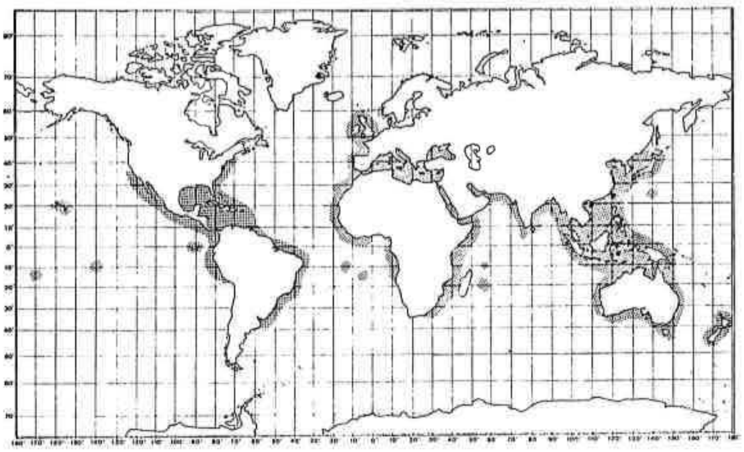


Figure 7: Distribution of members of the Thunnini tribe (skipjack, kawakawa, *Auxis sp.*) (from Collette and Nauen 1983).

(Shomura *et al.* 1994). Depth ranges from surface to about 260 m during the day, but is limited to near surface waters at night.

Kawakawa (*Euthynnus affinus*) is one of the three species of the *Euthynnus* genus, which occur worldwide in tropical and subtropical, primarily coastal waters (Figure 7). Each species has a particular geographical distribution, with hardly any overlap. Kawakawa are distributed throughout warm waters of Indo-Pacific, including oceanic islands and archipelagos. It is a small epipelagic, neritic tuna, occurring in water temperatures of 18 to 29°C, and commonly reaching 60 cm in fork length.

The two *Auxis* species, the bullet (*A. rochei*) and frigate (*A. thazard*) tuna, are also small epipelagic neritic fishes, occurring in the warm waters around some Pacific island groups (Figure 7). Size ranges between 25 and 40 cm.

Bonito (tribe Sardini)

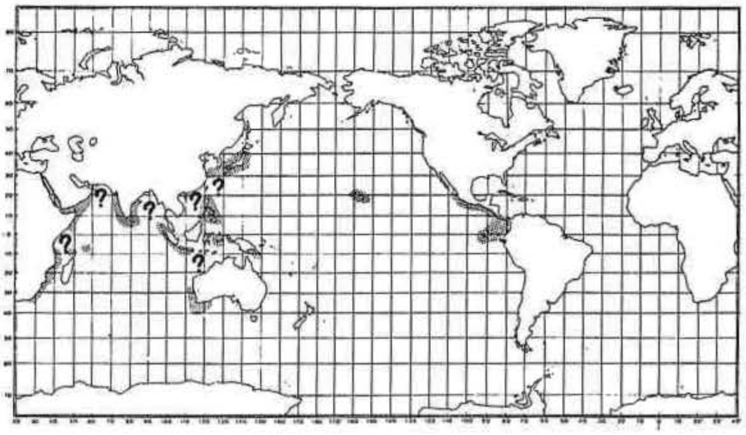
The bonitos are primarily epipelageic, coastal fishes, with a range of distributions for the various species (Figure 8). The slender tuna (*Allothunnus fallai*) has a global distribution in the southern oceans from 20 to 50°S. As juveniles they are found at surface temperatures between 19 and 24°C, with increasing size they gradually move into higher latitudes where water temperatures are lower. Maximum size recorded is 96 cm (Collette and Nauen 1983: 27). Several members of the Sarda genus are found in neritic Pacific waters, including the Eastern Pacific Bonito (*S. chiliensus*) and the Striped Bonito (*S. orientalis*).

The dogtooth tuna (*Gymnosarda unicolor*) is also a large member of this tribe, occurring in tropical waters with temperatures between 20 to 28°C. It has a patchy distribution in the tropical Indo-Pacific including Japan, the Philippines, Papua New Guinea, Australia and some islands of East Polynesia (Marquesas, Tuamotus, Pitcairn and Oeno). It is one of the few tuna which is primarily a reef dweller, occurring in mid-water along steeply sloping lagoon pinnacles, channel walls, and seaward reefs from the surface to a depth of at least 100 m (Myers 1989: 254). Maximum size is about 150 cm fork length.

Spanish mackerels (tribe Scomberomorini)

The Spanish mackerels are also coastal fishes, and may enter estuarine waters to feed. Most species have fairly restricted ranges in the Indo-West Pacific, with the exception of the wahoo.

striped bonito



Australian bonito

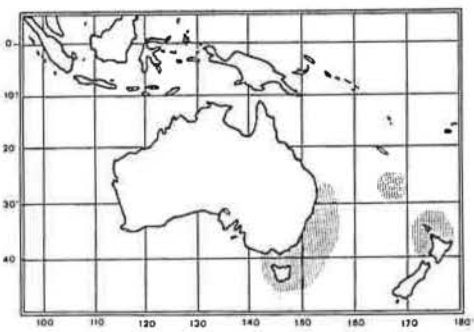


Figure 8: Distribution of members of the Sardini tribe (from Collette and Nauen 1983).

The wahoo (*Acanthocybium solandri*) is a frequently solitary, epipelagic, oceanic species, well known in the Pacific as a game fish. Size ranges between 100 and 170 cm in most surface fisheries (Collette and Nauen 1983: 26). Also found in the tropical Pacific, the Narrow Banded Spanish mackerel (*Scomberomorus commerson*) is often encountered patrolling reef drop-offs and sometimes lagoon waters (Myers 1989: 254).

Mackerels (tribe Scombrini)

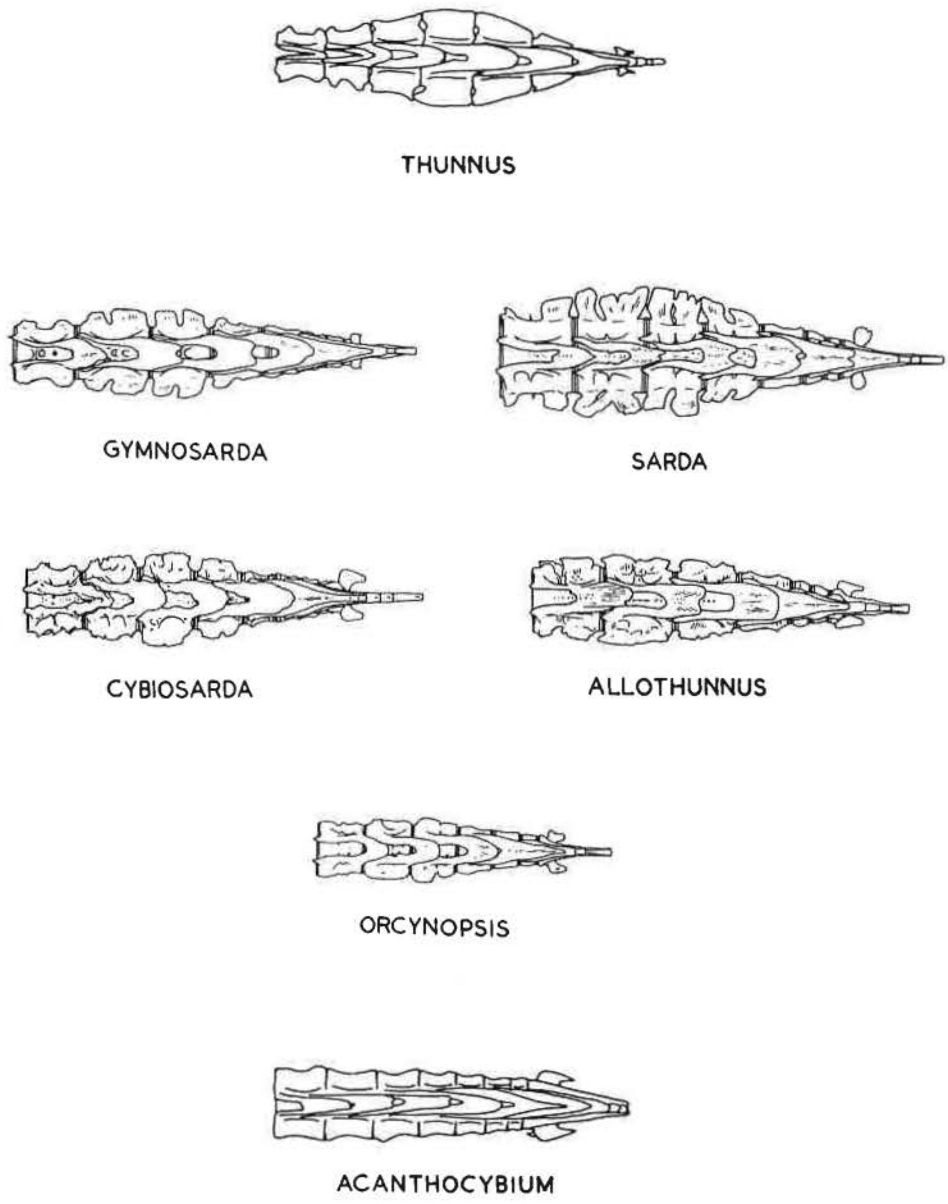
The mackerels are small fishes, which feed primarily on plankton. The three members of the genus *Rastrelliger* are epipelagic, neritic species, occurring in Indo-West Pacific where temperatures do not fall below 17°C. Size ranges between 10 to 20 cm for *R. brachysoma* and *R. faughni*, and up to 25 cm for *R. kanagurta*. *R. kanagurta* inhabits small coastal bays, harbours and deep lagoons, particularly in somewhat turbid plankton-rich waters. It often swims with its mouth open to strain the water with its gillrakers (Myers 1989: 254).

The Double-lined mackerel (*Grammatorcynus bilineatus*) is also found in the tropical and subtropical epipelagic waters of the Indo-West Pacific, often in shallow reef waters. It attains sizes of up to 60 cm.

Archaeological implications

The identification of fish taxa from archaeological sites in the Pacific is achieved at the Archaeozoology Laboratory, Museum of New Zealand using five paired mouthparts and various special bones which are diagnostic of particular taxa (Leach 1986). Scombridae osteology exhibits several characteristics which enable them to be distinguished from other fish families using comparative material. Their dentition consists of single rows of sharp teeth, in keeping with their mode of life as predators of fish and other sea creatures. Special adaptations to facilitate fast and powerful swimming are apparent in the vertebral column and tail bones. These include the caudal vertebrae with keel processes, and also the fusion of the hypural plate.

There is a general evolutionary trend within the Scombridae in the relative development of keels on the caudal peduncle (Collette and Chao 1975: 576-578) (Figure 9). The butterfly kingfish (*Gasterochisma melampus*), mackerels and Spanish mackerels lack supporting bony keels and have only external fleshy keels on the caudal peduncle. Starting with the bonitos,



–Dorsal view of last seven or eight preural centra to show structure of bony caudal keels in the five genera of Sardini plus *Acanthocybium* and *Thunnus* representing a more primitive (Scomberomorini) and a more advanced tribe (Thunnini) respectively.

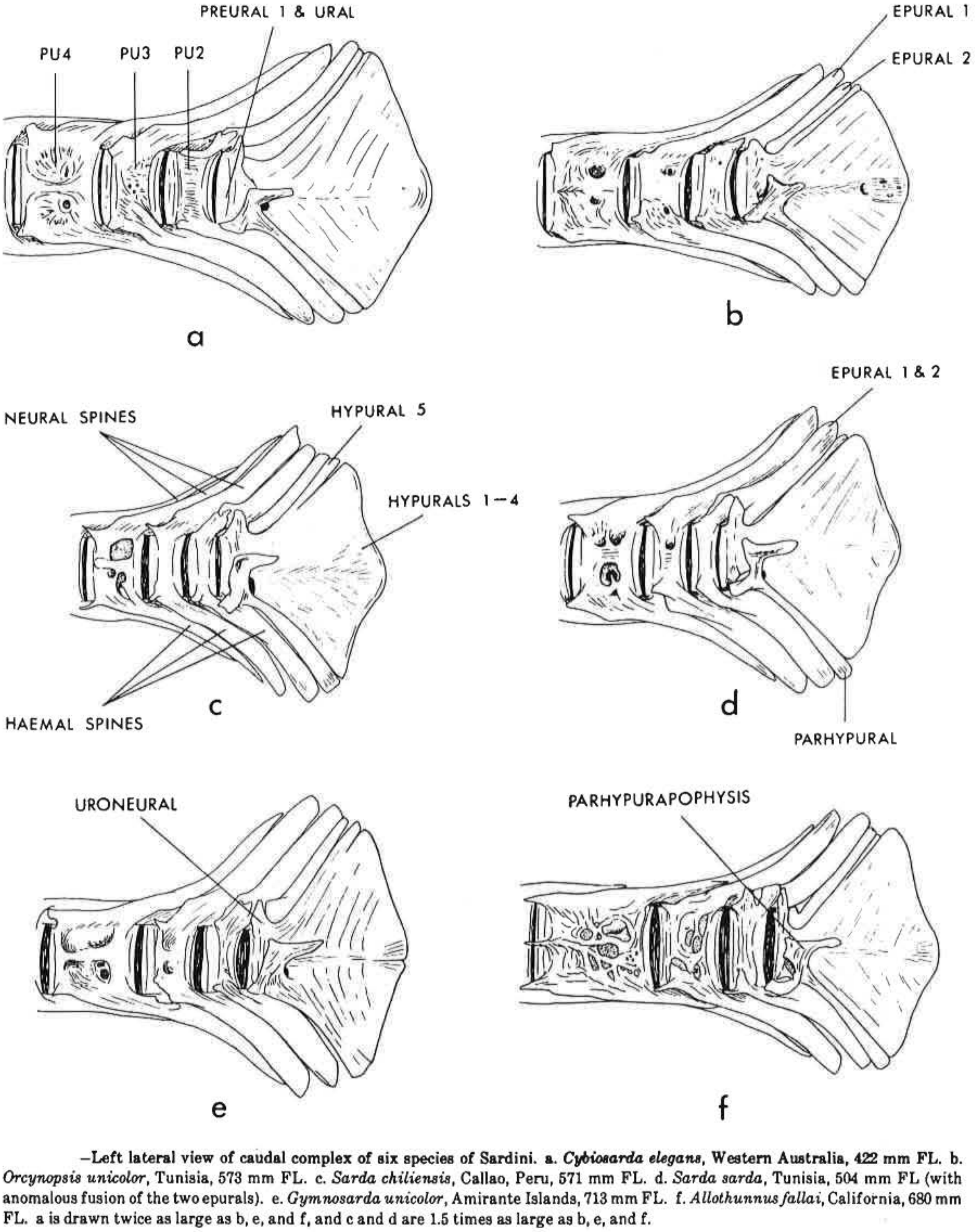
Figure 9: Keel processes in the Scombridae family (from Collette and Chao 1975: 577).

bony keels are developed below the largest pair of fleshy keels to strengthen and support them. In the bonitos they take two different forms. *Orcynopsis*, *Cybiosarda* and *Allothunnus* have low keels running the length of the vertebra involved. *Sarda* and *Gymnosarda* have wider keels as in the higher tunas, but they are divided into two segments on each vertebral surface. The higher tunas (*Thunnus* through to *Auxis*) possess a wide flattened plate which acts as a single functional unit over several vertebra.

In Scombrids the triangular hypural plate is composed of five fused hypural bones (Collette and Chao 1975:578) (Figure 10). The most dorsal (hypural 5) is not completely fused with the hypural plate in the bonitos or tunas. A hypural notch is present in the middle of the posterior margin of the hypural plate of the mackerels and Spanish mackerels. It is absent in all bonitos and tunas, except for a vestige in *Gymnosarda*. In all tunas and bonito, except for *Gymnosarda*, the parhypural is located between the first haemal spine and the lower margin of the hypural plate. In *Gymnosarda* the parhypural is fused with the hypural plate, as in *Acanthocybium* and some species of *Scomboromorus*.

Tuna have often been identified in archaeological sites in the Pacific solely on the basis of cranial anatomy (for example Dye 1990, Rolett 1989). Some researchers have also identified their presence in sites using bones from the caudal complex (for example Davidson, Fraser *et al.* n.d., Leach *et al.* 1997b, Chatan 1992). At present identifications are usually made to family level only, however, there may be significant differences within fish families which are obscured by this limited taxonomic level of identification. Given the number of species within the Scombridae family and the variation in behaviour and the environments they inhabit, lower level identifications where possible would be useful, particularly when research is directed towards questions about fishing strategies and inshore versus offshore resource use.

The relative lack of osteological differentiation below the family level, particularly of the cranial anatomy, can make intra-family level identifications difficult. This problem is exacerbated by the high commercial value of tunas which can be a prohibitive factor in the development of comprehensive reference collections. In the course of this study it was observed that Scombrid mouthparts recovered from archaeological sites were often highly fragile or incomplete. This could be related to the amount of oil in the bones. The high oil content of the oilfish (*Ruvettus* sp.) has been suggested as a reason for its absence in archaeological sites (Leach and Ward 1981: 96, Severance 1986:38). The fragility of these



–Left lateral view of caudal complex of six species of Sardini. a. *Cybiosarda elegans*, Western Australia, 422 mm FL. b. *Orcynopsis unicolor*, Tunisia, 573 mm FL. c. *Sarda chiliensis*, Callao, Peru, 571 mm FL. d. *Sarda sarda*, Tunisia, 504 mm FL (with anomalous fusion of the two epurals). e. *Gymnosarda unicolor*, Amirante Islands, 713 mm FL. f. *Allothunnus fallai*, California, 680 mm FL. a is drawn twice as large as b, e, and f, and c and d are 1.5 times as large as b, e, and f.

Figure 10: Structure of the hypural plate in the Scombridae family (from Collette and Chao 1975: 579).

bones means that processes which may aid in differentiation between species are more susceptible to damage, and are hence more likely to be affected by issues of preservation and recovery. The use of the caudal complex for identification has several implications. Firstly, where conditions for preservation of bones in sites are not good, the robust nature of these bones means they are more likely to survive intact. Secondly, with appropriate comparative material it may be possible to achieve lower level identifications using these bones. Lower level taxonomic identifications using caudal bones could therefore provide information on what species are present, but until all anatomical elements can confidently be identified to the same taxonomic level, family level identifications should still be used when considering relative abundances.

Two measures are commonly derived from the identification of fish bones in sites; the NISP (Number of Identified Specimens) and the MNI (Minimum Number of Individuals). Although both figures are used as a way of establishing the relative abundance of different fish in sites, strictly speaking the NISP count is a measure of bones in sites, as opposed to fish. Increasingly, fishbone analysis in the Pacific involves the identification of all the bones recovered from sites, to element at least and taxa where possible (Walter *et al.* 1996). The data provided in such cases enables other issues to be considered such as taphonomy and the role of cultural processes such as butchering in site formation. Problems with both methods of quantification of relative abundance have been identified.

The NISP value is affected by interdependence (Grayson 1984), as the number of identified elements representing a specific taxon may all come from the same individual. Furthermore, fragments which come from the same element may also each be assigned a value. This problem is compounded by the selection of elements used for identification. Some fish are identified solely by mouthparts, others by these and special bones. Because such taxa are identified by a wider range of elements, they have a greater chance of being identified, and hence are also likely to have a greater abundance. Furthermore, estimates of abundance will also be affected by the number of diagnostic elements present for a particular fish. Diodontidae, in particular, have a large number of dermal spines per fish. If bones from the caudal complex, including vertebrae are identified for tuna, the NISP may be inflated compared to other fish species routinely identified by mouthparts only. It is therefore important that researchers report what elements have been used for identification, and in the calculation of abundance measures.

In this study, MNIs were calculated to enable consideration of the fish caught, as represented by fish bones in a site. This is particularly useful when considering taxa such as tuna, where element selection may have inflated the NISP count, or conversely, poor preservation may mean the less robust elements, such as cranial bones, are under represented. The MNI figure enables the proportions of different fish in the catch to be determined, and hence their importance in relation to each other. Alternatively, some researchers have attempted to determine absolute values for total catches or caloric values. An awareness of the role of taphonomic processes in bone destruction has contributed to the current lack of popularity for this type of approach (Lyman 1994: 111). The MNI figure itself has been criticised for problems of aggregation (Grayson 1984). The MNI count varies depending on how the faunal material is aggregated, for example, by excavation layer, cultural layer, square or whole site. As the unit of analysis becomes more divisive, the overall MNI increases; when the entire assemblage is treated as one unit, the smallest MNI value is generated (Grayson 1984). Although the absolute MNIs generated using different methods of aggregation will vary, relative abundance should still be preserved (Leach 1997: 28).

A further problem with the use of MNI as a measure of abundance concerns the relationship between MNI and the size of the faunal assemblage from which it is calculated. As the sample size increases, the contribution of each individual bone to the MNI decreases. While it is acceptable to compare assemblages of similar sizes, the comparison of unequally sized assemblages may not be valid. This problem is exacerbated when more than one species represented by different quantities of identified bone are compared, as MNI will tend to exaggerate the presence of the rarer species (Smith 1985: 111). Comparisons between assemblages with varying sample sizes should be viewed with caution.

Tuna in archaeological sites in the Pacific

The assemblages used for this research form part of the Archaeozoology Laboratory, Museum of New Zealand's accumulated database of Pacific fish bone identifications. This database has been developed with the aim of establishing and maintaining a record of the increasing number of archaeological fish bone assemblages excavated in the Pacific. The development and application of a standardised method of fishbone analysis and the associated computer database management system provides not only a record of fish remains but also a tool which enables manipulation of data as directed by research aims (Leach 1986). The assemblages used in this research were chosen because the techniques used in analysis were well-documented and consistently applied. A comprehensive coverage of sites from the Pacific region falls outside the parameters of this study; however, it was possible to examine assemblages from a range of sites from different areas and time periods.

At present, the data is in two forms in the database. Identifications made during early analyses have been used to calculate MNIs for each site. More recently, the database has been extended to enable the calculation of both NISP and MNI. It is intended in the near future to re-format the data from early analyses to enable NISP to be calculated for these assemblages also (Foss Leach pers. com.). The percentage of tuna in all sites in the database, using MNI counts, is shown in Figure 11. Where available, the tuna bones identified in sites are shown as a percentage of NISP in Figure 12. The location of sites is shown in Figure 13. The variable distribution of tuna in archaeological sites in the Pacific is clearly demonstrated, in both the NISP and MNI figures. This contrasts with the currently known natural distribution of members of this fish family. Based on reconstructions of the fish catch, using MNI, several assemblages are notable for the high proportions of tuna they contain. These are from the two Marquesan sites of Te Anapua and Hane, and another East Polynesian site of Fa'ahia. Assemblages from Ma'uke, Motupore, Fais and Nukuoro also contain relatively greater proportions of tuna in comparison with the remainder of assemblages shown.

From this survey, four sites have been chosen for more in depth study, including metrical analysis, in order to investigate the high occurrence of tuna remains in some sites. These are Hane, Te Anapua, Fa'ahia and Motupore. Results will be discussed in Chapters 5 and 6, following the investigation of the context of tuna fishing, firstly as a fishing activity, and secondly, within the social milieu.

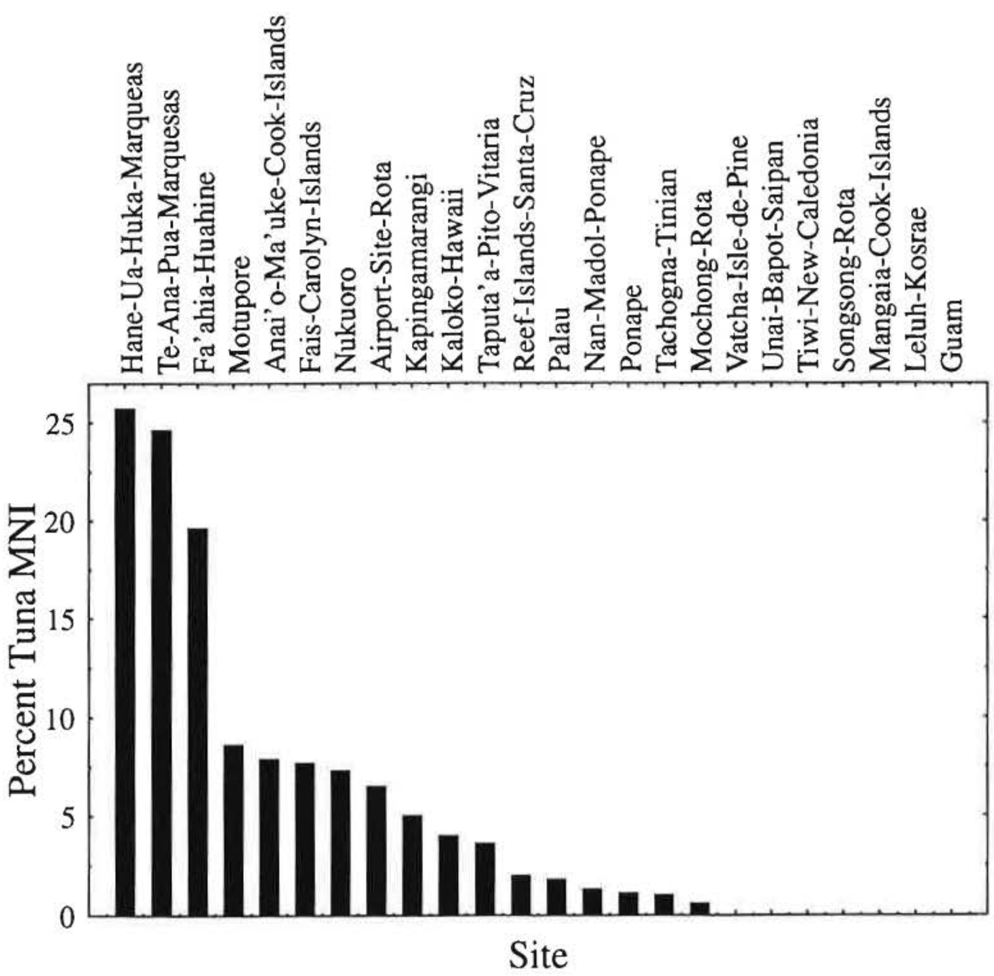


Figure 11: The proportions of tuna (MNI) in a number of Pacific island sites, held in the Archaeozoology Laboratory, Museum of New Zealand database.

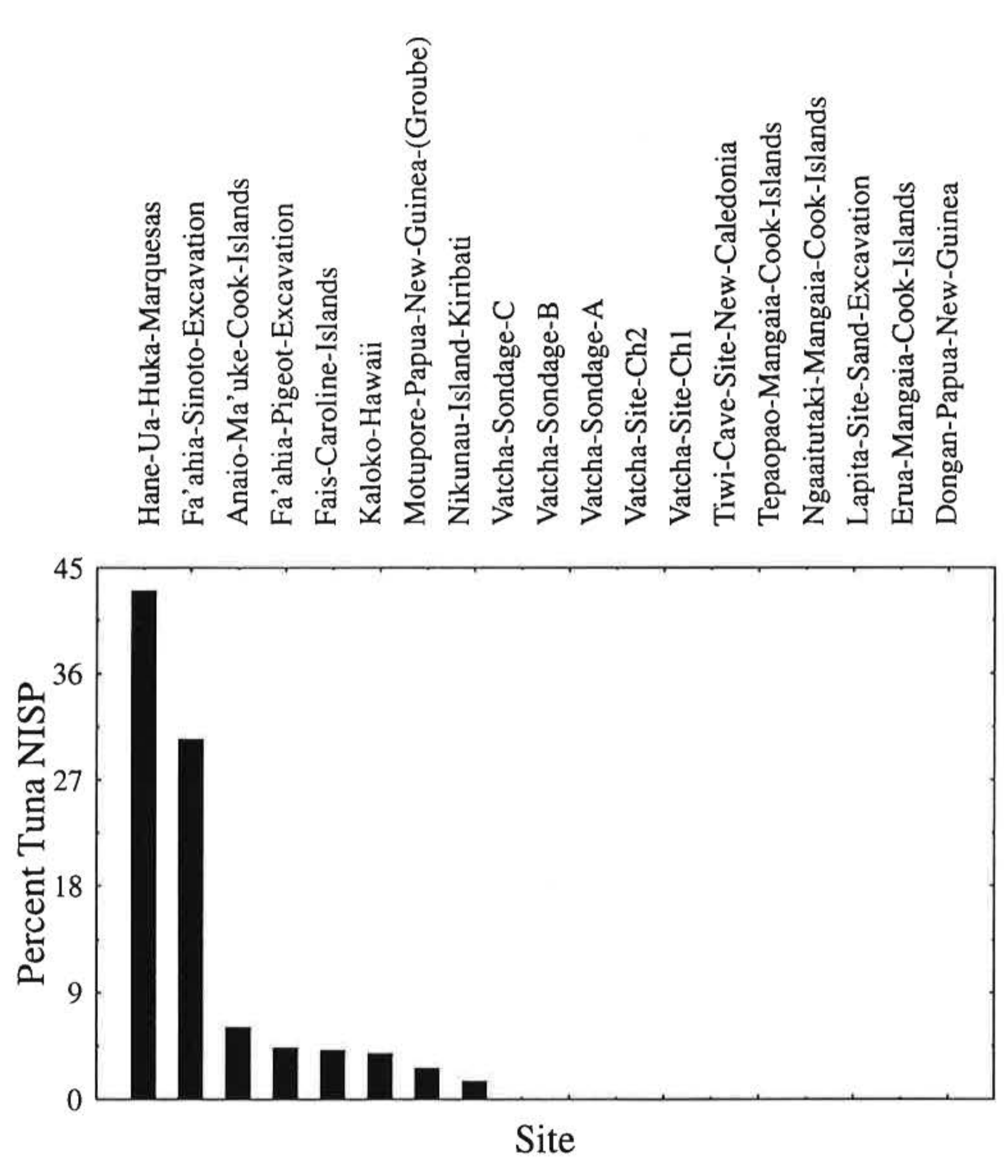


Figure 12: The proportions of tuna (NISP) in a number of Pacific island sites, held in the Archaeozoology Laboratory, Museum of New Zealand database.

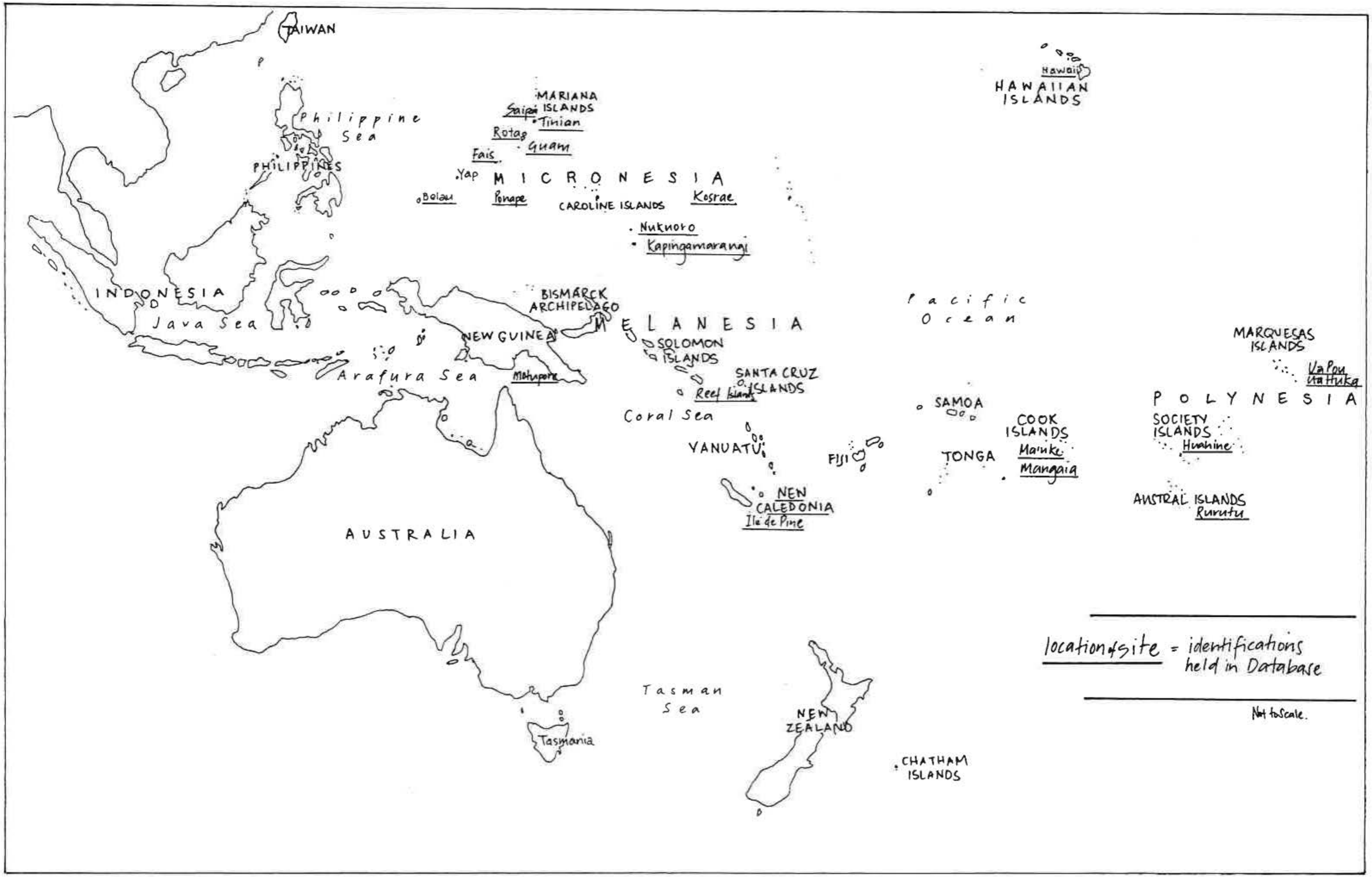


Figure 13: Locations of sites in the Pacific region with fish bone collections held in the Archaeozoology Laboratory, Museum of New Zealand database.

3: Tuna fishing strategies in the Pacific

The contention that tuna from archaeological sites were caught using the ethnohistorically well documented method of trolling is a common one in Pacific archaeology. This is an oversimplification, as will be demonstrated shortly. The purpose of this chapter is to review the contemporary and ethnohistoric literature relating to tuna fishing strategies in the Pacific, and then evaluate the extent to which any or all of these can be inferred from archaeological evidence. The chapter begins with a review of the main methods used to catch tuna in the Pacific, followed by a discussion of the way in which these methods articulate with other variables to form strategies for catching tuna. Finally, these strategies will be considered from an archaeological perspective.

When reviewing historical accounts of fishing in the Pacific region it becomes apparent that terms such as method, technique and strategy are often used interchangeably in the description of fishing behaviour. However, in the following discussion a distinction is drawn between a fishing method, and a fishing strategy. A method (or technique) describes a specific way of doing something. Methods are often defined with reference to the technology used, for example, netting or spearing. A fishing strategy implies a plan using a certain method, but also taking into account factors such as fish behaviour and environmental conditions which can effect the outcome. A strategy, in effect, aims to optimise the use of a particular method. Strategies may be selective and designed to target particular species or types of fish, or may be more general and incorporate an element of opportunism.

Tuna fishing methods

Trolling for tuna has clearly grasped the imagination of many researchers who have worked in the Pacific. Yet within this overall tradition there are a wide range of local variations. In Polynesia this method has been often referred to as "bonito fishing" (for example Burrows 1936: 151, Hornell 1950: 74, Kennedy 1930: 39, Nordhoff 1930: 233). The term bonito in this usage cannot be seen to refer to a specific biological taxon, and probably refers to what is now known as skipjack tuna (*Katsuwonus pelamis*).

In the past, trolling involved the use of an often special type of canoe powered by paddle or sail; however, today outboard motors are also used. These canoes must be capable of handling sea conditions encountered beyond the reef. Te Rangi Hiroa (Buck 1930: 371) describes the "bonito canoe" from Samoa as a paddled plank canoe with an outrigger, that was designed for lightness and speed when pursuing the schools of fish. Crew numbers vary depending on the style of the canoe. Paddled canoe crews in Polynesia were usually made up of between 2 to 7 people (Buck 1930: 371, Gillet 1985: 28, Hornell 1950: 76, Kennedy 1930: Figure 23, Nordhoff 1930: 250). Figure 14 shows a sketch of a paddled canoe from the Ellice Islands, with a crew of four. Sailing canoes from the Carolines are today about 8 to 9 meters in length (Figure 15), and have crews from 6 to 15 people (Gillet 1987: 9), while those from the South Islands of Palau are smaller and are only usually crewed by two people (Johannes and Black 1981: 91). The fishing gear consists of a pole or rod with several lines, with lures attached to each. Canoes often had rests or loops for the rod to rest in at the stern (Figure 16).

Trolling is a method which targets fish which are swimming on or near the surface. Reinman (1967: 138) states that bonito (skipjack) are rarely caught by any other method than a trolled lure, which is likely given their vertical distribution. The lure is normally dragged behind, or cast (Figure 17), from the stern of the moving canoe, however, Kaschko (1976: 196) has described a method from the Solomon Islands where a lure is cast from the bow of a canoe into schools of surface feeding tuna. Casting from a stationary canoe for *aku* (skipjack) and kawakawa is also recorded in Hawaii from the early 20th century (Iversen *et al.* 1990: 25). The lure has a number of physical properties called 'attractors', which trigger reflexes in pelagic carnivores resulting in the fish pursuing and biting the lure, without much regard to its form. These attractors are features like eyes, hackles, reflected colour or light flashes, air bubbles on hackles, or particular vibrations in the water. Particular combinations of several attractors will stimulate a certain species of fish. Figures 18-20 show the sequence of events during a tuna fishing expedition in the Ellice Islands. The canoes are the same style as that illustrated in Figure14.

Lures used in the Pacific are usually composite hooks, consisting of two main components: the shank, and the point. These are lashed together, and hackles may also be added. Figure 21 illustrates the various components of a lure. This type of lure is known as *pa* in Polynesia, and

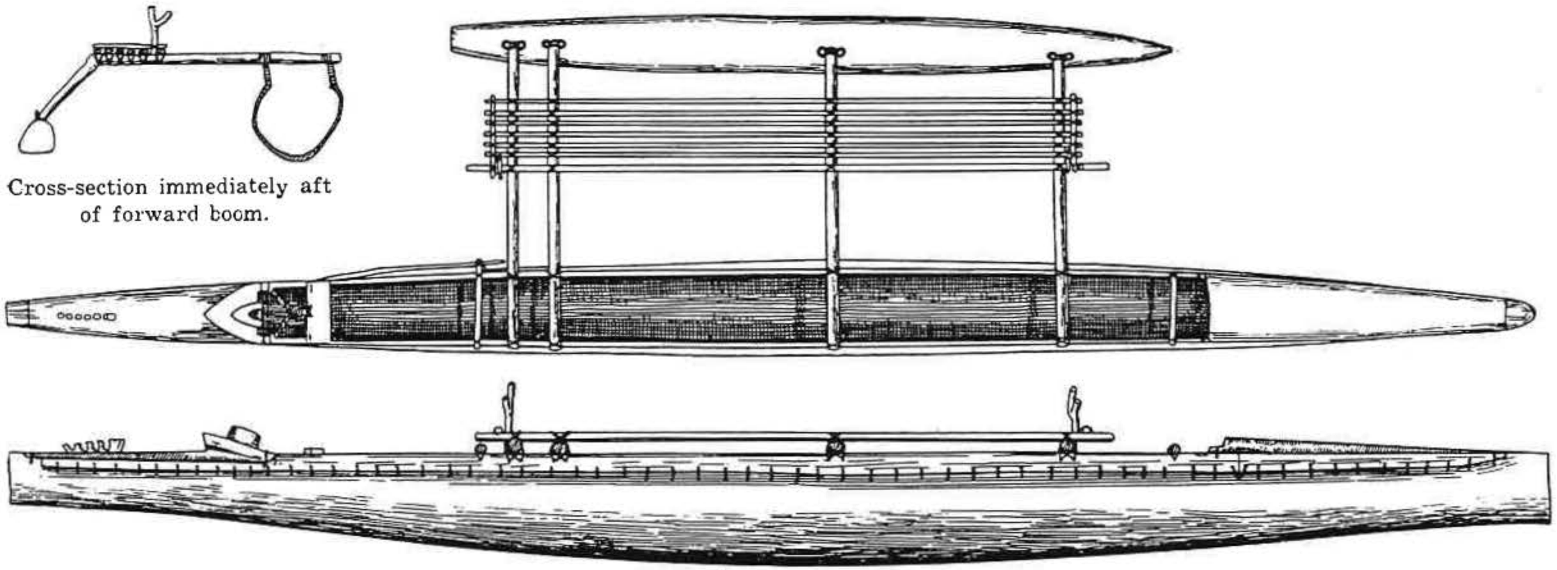


Figure 14: Sketch of paddled canoe from the Ellice Islands (from Kennedy 1930).

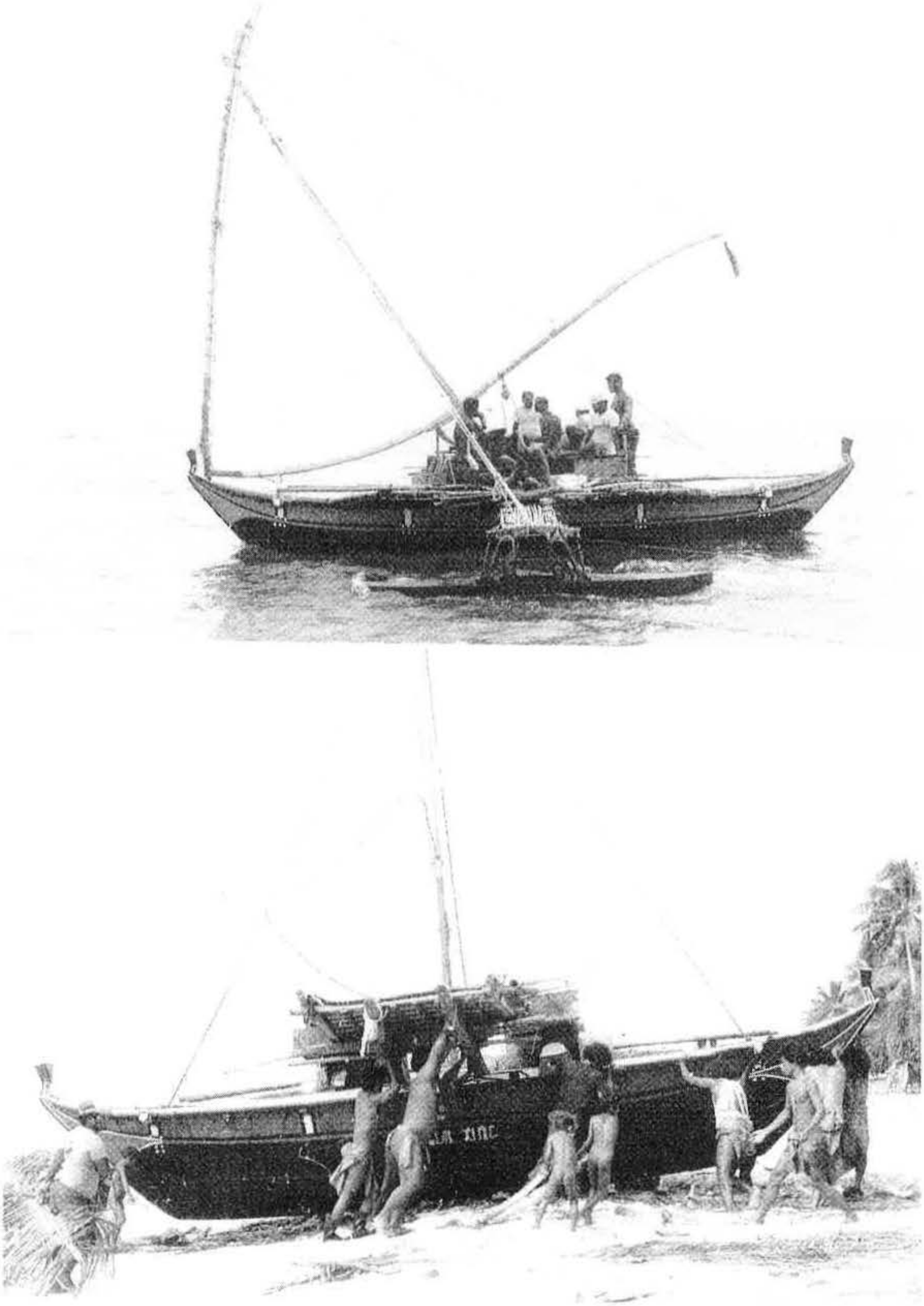


Figure 15: Sailing canoes of Satawal (from Gillet 1987: 10).

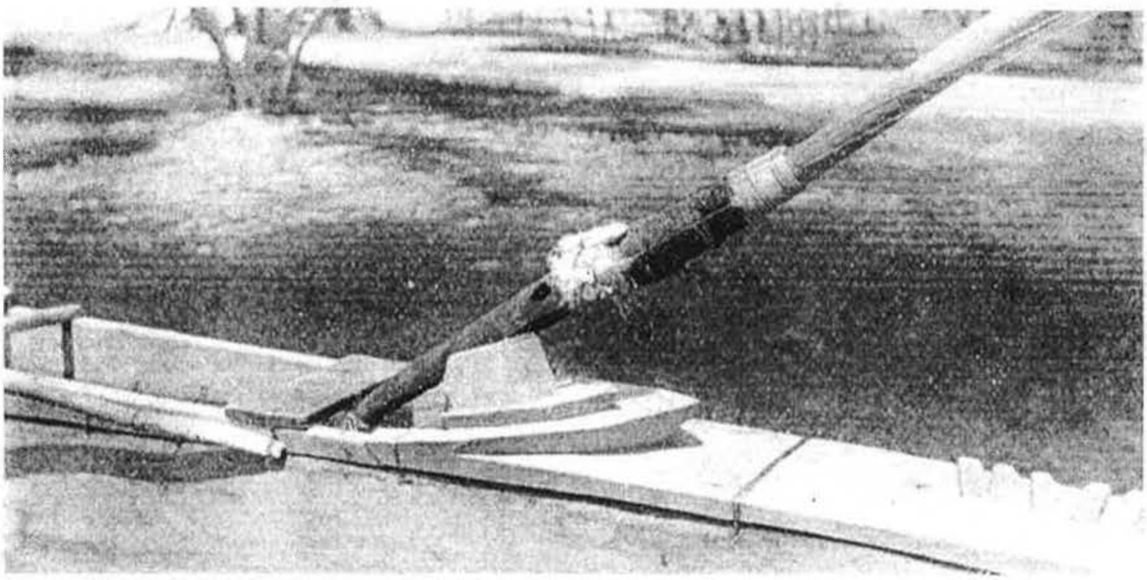


Figure 16. Butt end of rod in rest; two lures are attached (from Kennedy 1930).

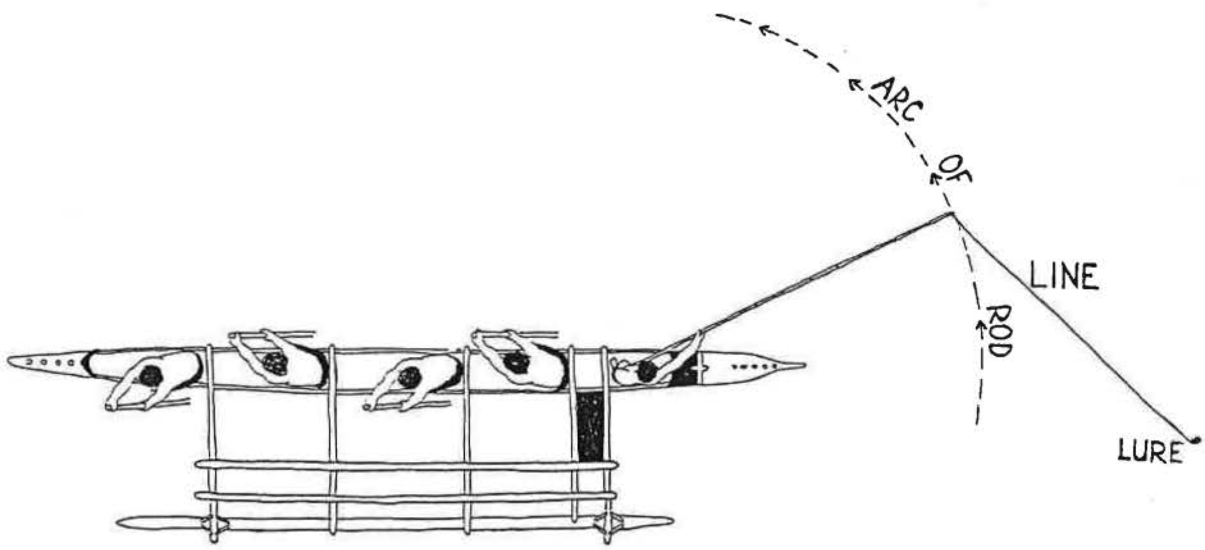
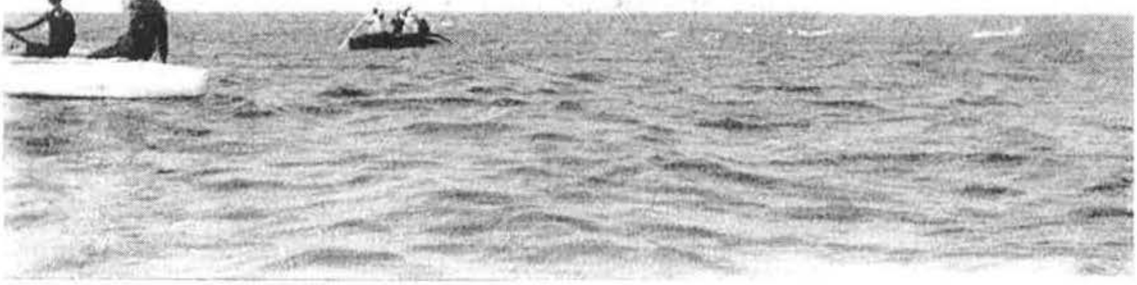


Figure 17: Casting the lure during Tokelau skipjack fishing (Hooper and Huntsman 1991: 250).

a



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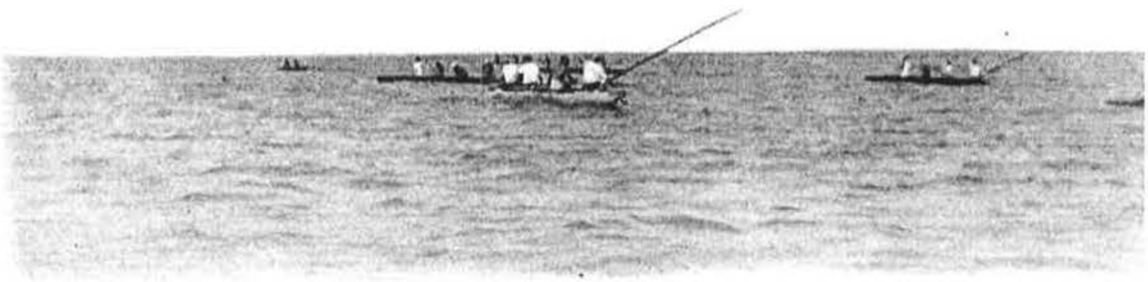
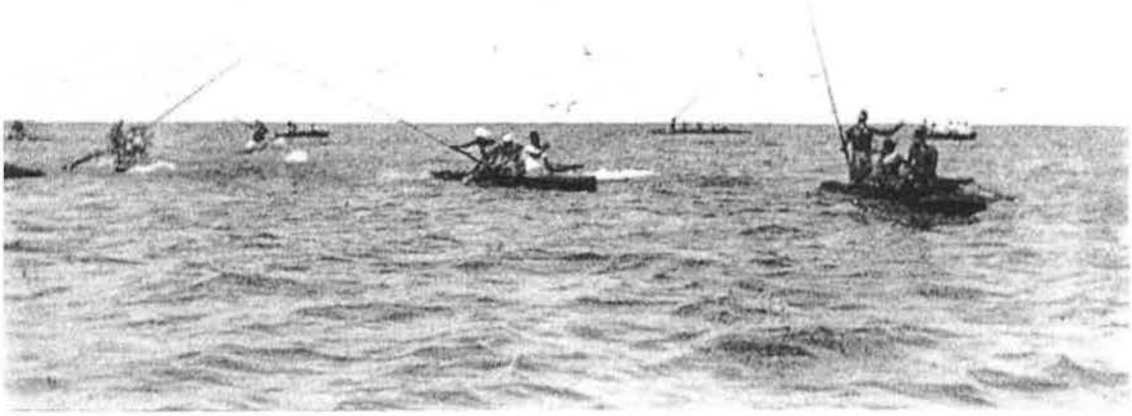


c

Figure 18: Tuna fishing expedition in the Ellice Islands (from Kennedy 1930).
a: A tuna school as it appears before the canoes arrive.
b: Nearing a school, rods at the trolling angle in the stern.
c: Trolling on the fishing grounds.

a



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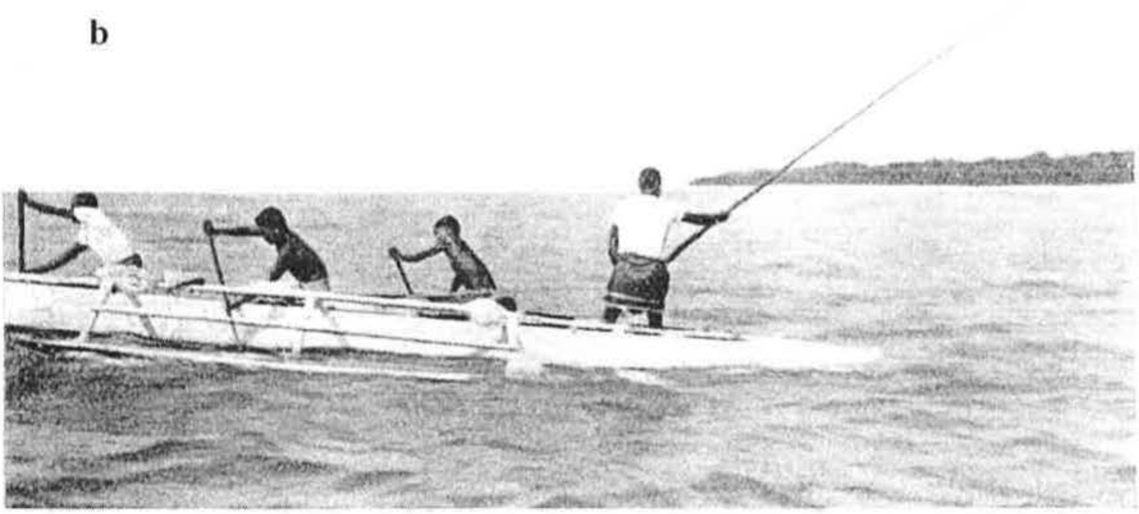

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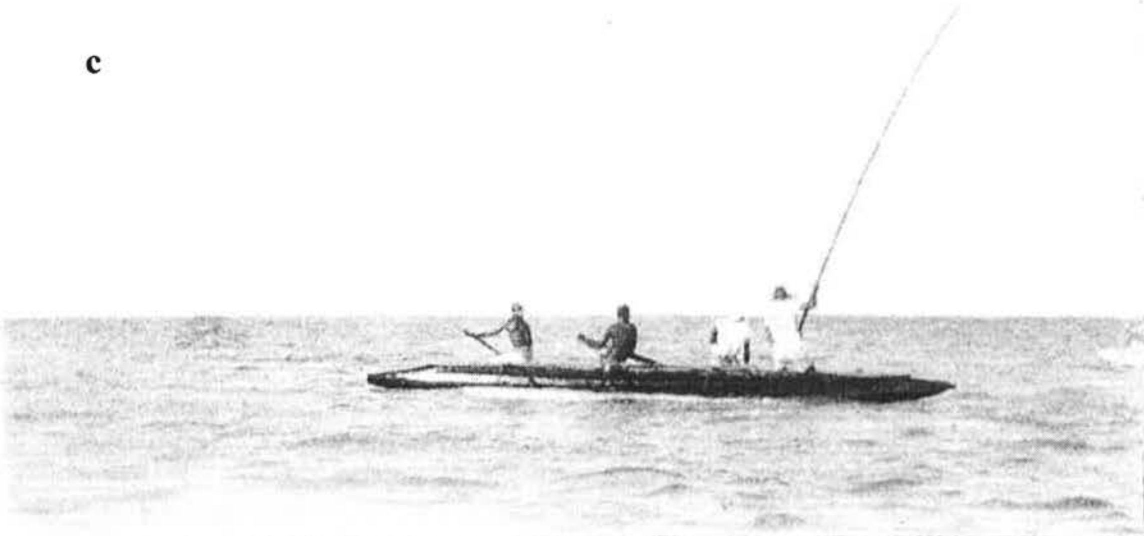


Figure 19: Tuna fishing expedition in the Ellice Islands (from Kennedy 1930).
a: In the middle of a school. The *tautai* of the nearest canoe is changing his lure.
b: Fishing in a school.
c: *Tautai* swinging in a fish.

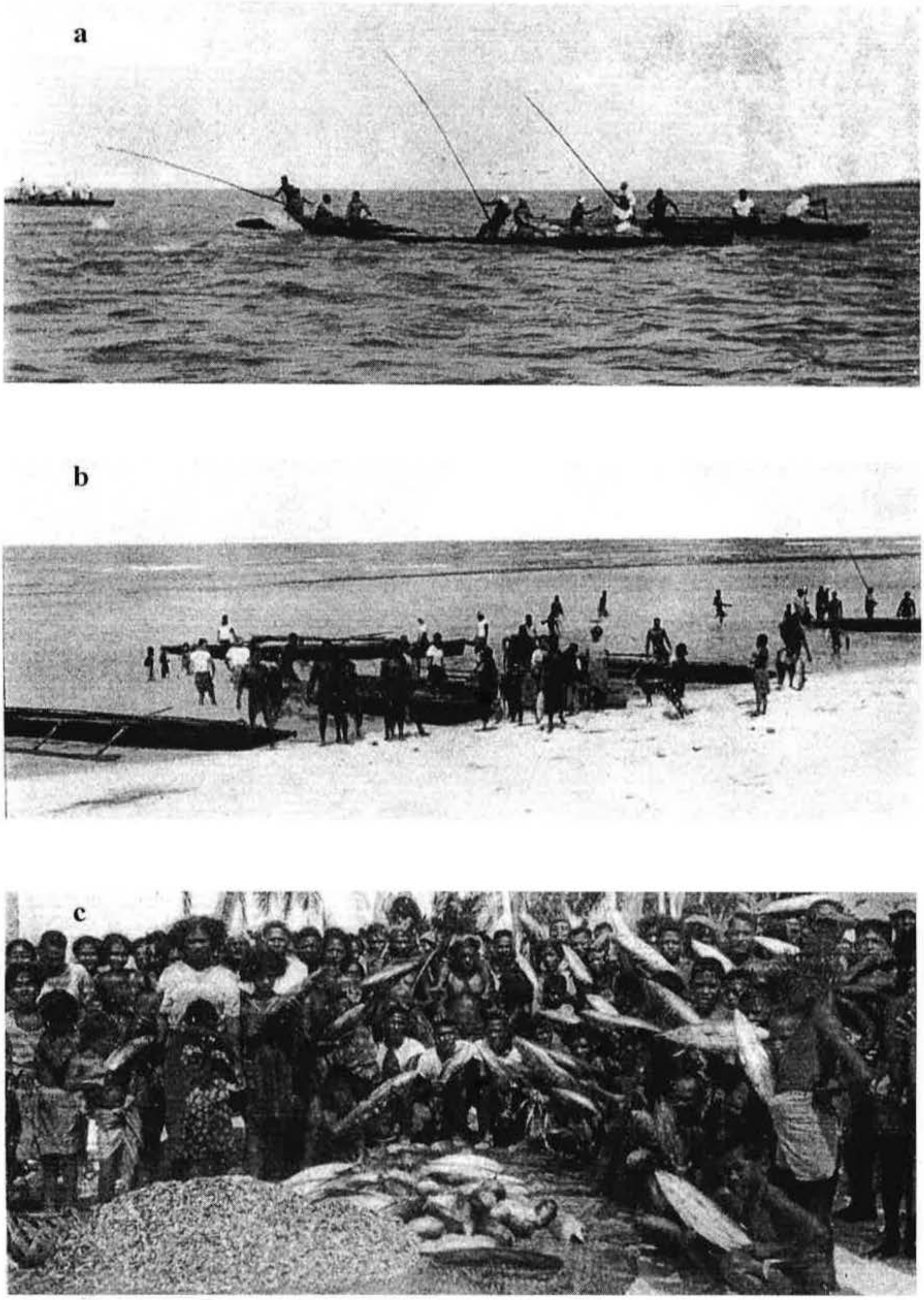


Figure 20: Tuna fishing expedition in the Ellice Islands (from Kennedy 1930).
a: The central *tautai* has let his fish get down, and is having some difficulty landing it.
b: The return of the canoes.
c: The catch, included are a pile of *o*, the small fish on which skipjack feed. They were netted by one of the canoes, before the arrival of the tuna.

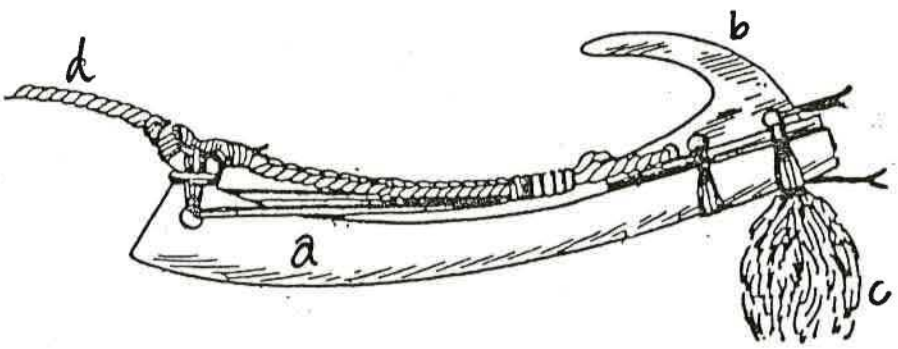


Figure 21: Components of a trolling lure (from Kennedy 1930).

a: shank

b: point

c: hackle

d: line

different types of *pa* are distinguished by name. For example in Hawaii, *pa hi aku* refers to lures for "bonito" fishing (Iversen *et al.* 1990: 26), on Uvea they were called *pa atu* (Burrows 1937: 109), and in Samoa *pa`atu* (Buck 1930: 497). One piece lures made from shell have been described ethnographically from the Solomon Islands (Kaschko 1976: 194), while archaeological excavations at To`aga, Samoa, have produced similar shaped hooks made from *Trochus* shell. These have been identified as trolling lures by Kirch (1997: 201), and appear to possess groves at the base for hackle attachment, although they are similar to one-piece hooks from elsewhere in the Pacific. They are shown in Figure 22.

Before the availability of artificial materials in the Pacific, the most favoured material for the shank was pearl shell. Depending on the availability of pearl shell, other materials were used including different types of shell, bone and stone (Anell 1955, Reinman 1967). Pearl shell, bone and turtle shell were used for point manufacture, and feather or fibre for hackles (Reinman 1967). Points are not barbed, to facilitate the easy removal of the fish. The presence of barbs on lures present in museum collections is argued to be to prevent fish becoming deeply hooked, as opposed to keeping them on the hook (Nordhoff 1930: 246). Today in many places pearl shell and turtle shell remain the predominant material for lures (Gillet 1985: 14, 1987: 14, Lieber 1994: 81), however, lines made from bark and other fibres were first replaced by cotton line, and more recently by monofilament lines (Gillet 1985: 17, 1987: 11). A selection of trolling lures from the Pacific, held in Museum collections, is shown in Figure 23.

The use of one piece hooks for catching tuna has also been documented in the Pacific. A variety of methods using these hooks have been recorded, at a range of depths. Hooks are baited, and tend to be used in conjunction with chum (Gillet 1985: 21, Iversen *et al.* 1990: 27, Nordhoff 1930: 157). Chumming involves the dispersal of bait in the water. Often this is achieved by wrapping a sinker stone and the chum in a leaf parcel, which is held together with a slip knot on the line. This package is let down until the desired depth has been reached, whereupon a jerk on the line releases the wrapping. This activity also commonly takes place outside the reef and thus requires a canoe.

In the Society Islands the *tira* was a specialist piece of equipment used to take sub-surface tuna on a baited hook (Nordhoff 1930: 141-153). Nordhoff identifies the tuna caught as albacore,

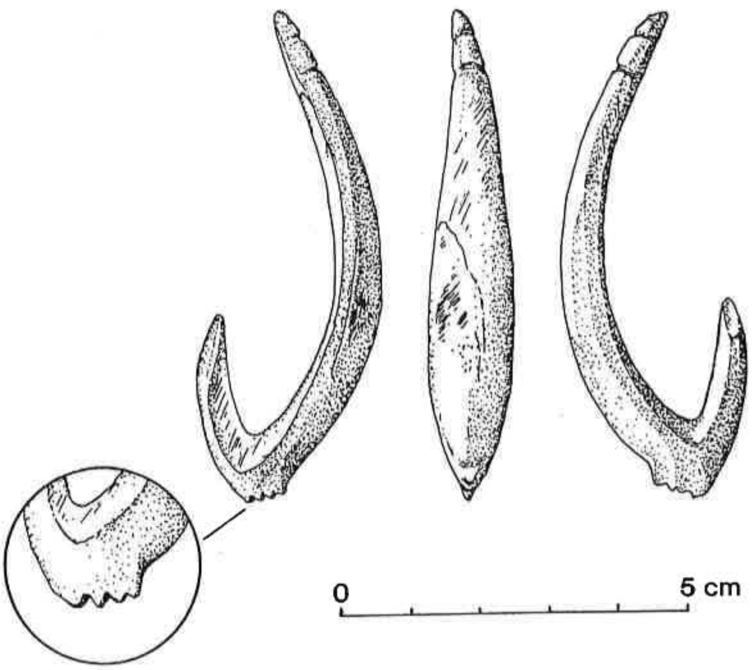
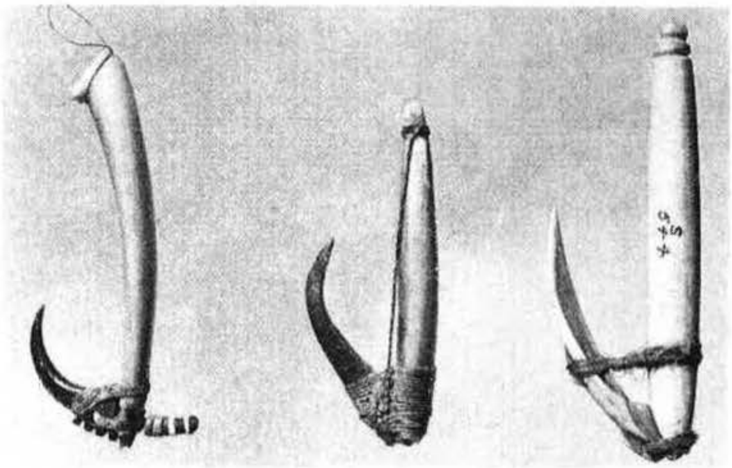


Figure 22: One-piece lure from the Talepakemalai site, Mussau Islands (Kirch 1997: 201).

a

b



c

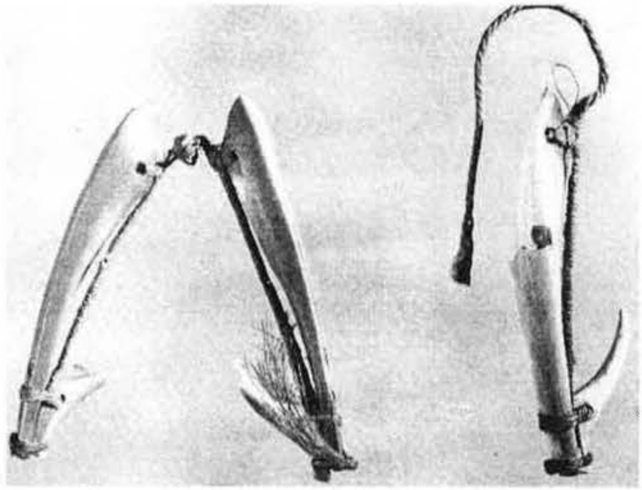


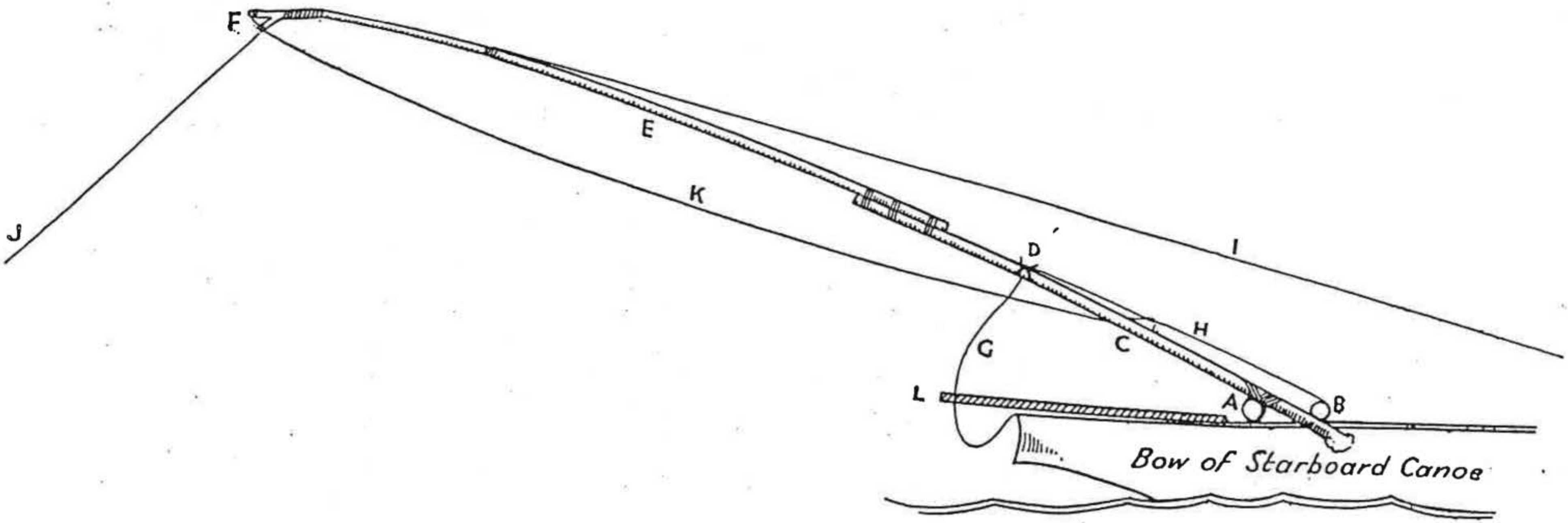
Figure 23. Some trolling lures from the Pacific (Nordhoff 1930).
a: Marshall Island and Samoa
b: Fiji, Sandwich Islands and New Guinea
c: Society Islands

but observes that at least two species may exist, one with yellow pectoral fins. Albacore, yellowfin and bigeye tuna may have formed components of the catch. The *tira* was a double canoe, equipped with a kind of crane (Figure 24), and a large floating basket from which live bait was thrown. *Tira* means mast, and it is from this structure that the method takes its name. The fishing was carried out only in small, well-defined areas of the sea. These "albacore holes" were named, and in the past were privately owned and managed as a valuable resource. The existence of such places was explained to Nordhoff (1930: 143) by an old fisherman as follows: "An albacore hole is a place in the sea where conflicting currents set up a condition like the *nini* (the "cowlick") on the back of your head. The small fry, moving with the currents, are swept into such places from all sides, and the albacore wait there for their food."

In the 1930s when Nordhoff wrote his account of fishing in the Societies, the hooks used in *tira* fishing were all made from metal, and had been in use for so long that he was unable to obtain a description of a pre-European hook. He surmises that the design was based on an older type, which would have been made from heavy pearl shell. Only one hook is used at a time when tira fishing, although a spare hook and line is attached to the *tairi* (rod). When the albacore hole was reached, the bait fish was thrown out by the captain as the canoe transcribed a large circle. When the albacore were seen rising to feed on the surface, the hook, baited with a whole fish, was trolled behind the slowly paddled canoe. When a fish was hooked the crane was raised and the fish disengaged from the hook, while a spare line was being re-baited and let out. Nordhoff (1930: 257) also mentioned the presence of a similar method of fishing observed in Hawaii in the late 19^{th} century.

Severance describes another method of fishing from Hawaii which takes place over a specific location, in his discussion of fishing in the archaeological site of Kahalu`u, Hawaii Island.

> Larger ahi [yellowfin and bigeye] were quite possibly caught with the "*palau ahi*" technique that wraps a baited hook and chum around a stone which is released when it reaches a marked depth (30-70 fathoms) over an *ahi koa*. Contemporary fishermen use larger rotating hooks with this technique, but the ethnohistoric literature is also unclear whether rotating or larger two piece jabbing hooks were preferred for this technique. Relatively large *ahi* could be captured with weaker hooks than one might expect because of the behaviour of the fish. When *ahi* are hooked, they dive deep very fast and the line is allowed to uncoil over the side of the canoe. They stop after reaching a certain depth, and can be drawn back to the surface with adequate pressure. (cited in Iversen *et al.* 1990: 27)



Diagrammatic sketch of *tira* (not drawn to scale).

A—*Rio.*
B—*Iato mua.*
C—*Pu.*
D—*U.*
E—*Tairi.*
F—*Tama'a.*
G—*Tauratumua.*
H—*Taurahia.*
I—*Tauraturoa.*
J—*Ro'a* in use.
K—*R'oa* not in use.
L—*Ihuva'a.*

Figure 24: Diagrammatic sketch of the *tira* (from Nordhoff 1930: 165).

Most of the named varieties of fish-hook (both lures and one-piece hooks) from Nukuoro, a Polynesian outlier in the Central Pacific, were used for catching pelagic fish (Davidson and Leach 1996). Large examples of two one-piece hook forms, the *maimoni* and *buledanga,* were used with the intention of catching tuna. Nukuoro fishermen regarded these hooks as suitable, and indeed intended, for trolling (Davidson and Leach 1996: 14).

Nets and leaf sweeps have also been used in the Pacific to catch tuna. The people of Doubtless Bay in Papua New Guinea set nets across channels in Oyster Bay where tuna pass through on a seasonal basis (Pulsford 1975: 108-109). Posts are maintained on each side of the channels, which support the nets. Canoes are stationed at the opening, forming a funnel to direct fish in to the nets. When the fish are sighted stones are thrown into the sea behind the fish to hurry them into the nets and discourage them from turning away. When the tuna have all passed inside a man swims with a loose end of the net across the channel, sealing off the retreat. The net is then pulled in closer and closer around the fish which, when they attempt to pass through the net, become entangled. The fishermen then dive into the water and capture the fish, which are handed up to the waiting canoes (Figure 25). Skipjack are also known historically to have been caught with large nets and coconut frond sweeps on lagoon beaches during seasonal aggregations on Ant Atoll near Ponape and on other atolls north and south of Truk (Severance 1986: 40).

Tuna fishing strategies

As outlined in the introduction to this chapter, the phrase 'fishing strategy' is used here in a specific sense, and encompasses a range of variables. Kirch and Dye (1979: 55) have defined a fishing strategy as consisting of the integration of technology, behaviour and environment. Goto (1986: 22) considers a fishing strategy to involve consideration of:

i) the nature and amount of the resource to be procured,

ii) the location of the resource, and

iii) fishing seasons, and

iv) the employment of an efficient method or gear.

In particular, given the highly transitory nature of tuna movements, detailed knowledge of tuna behaviour is important. Most strategies targeting aggregations of tuna incorporate an element

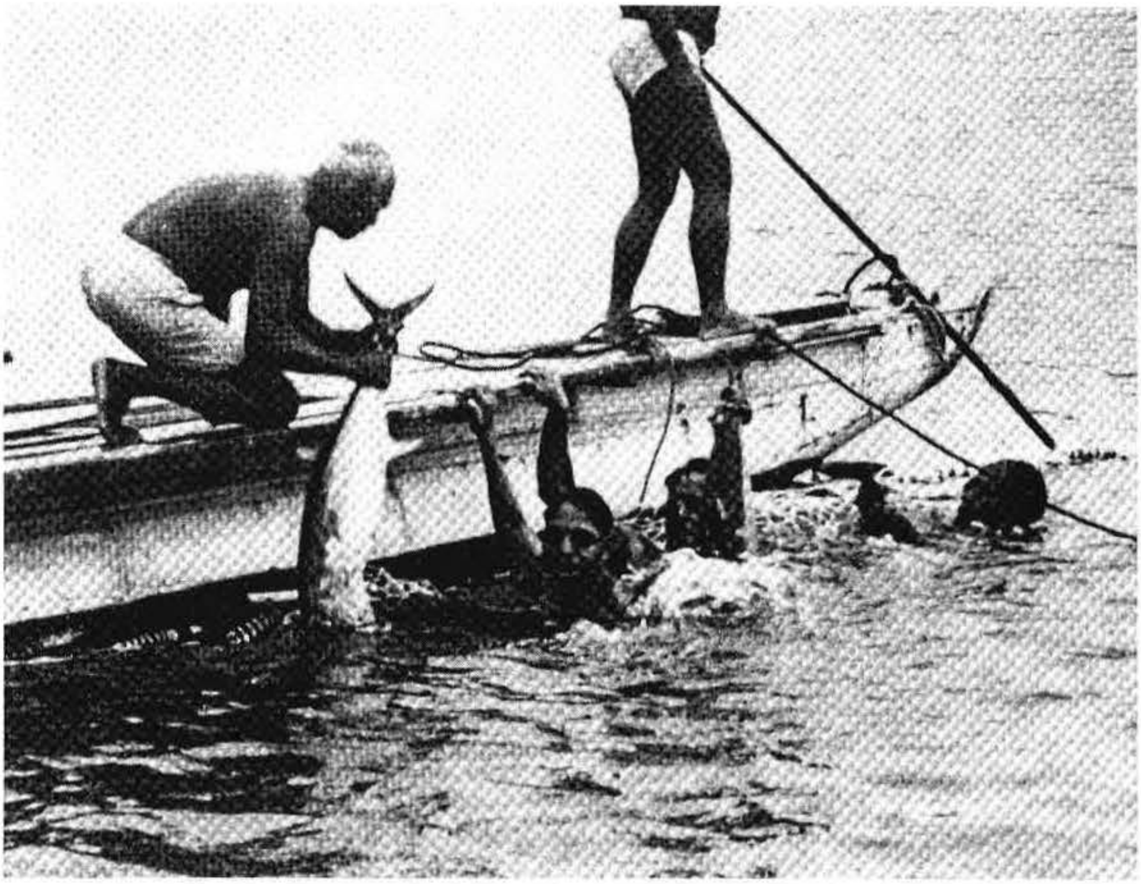


Figure 25: Tuna fishing in Oyster Bay, Papau New Guinea. On the left one fisherman is lifting a *kidukidu* carefully into the canoe. In the centre one is half way up and a third on the right is just to be lifted from the water. Trailing to the right is the encircling net. (from Pulsford 1975).

of seasonality. This is in part due to tuna movements, but also due to environmental constraints acting on fishing gear.

Trolling requires a particular set of sea conditions for the technology used. The water needs to be relatively calm, not only for the lure to work effectively, but also due to canoe requirements. Calm water is also an important requirement of the tuna themselves. As they attack from below, they need to be able to see the small fish which are their prey. The same is true for the sea birds which also dive for surface schools of small fish driven to the surface. Although summer is the season of most storms in eastern Polynesia, it is also the time of lengthy calms. Storms are infrequent during winter, but the trade winds which blow continuously can build up swells of a magnitude unfavourable to fishing except in protected waters. In Tahiti the summer months were known as the season of *te tai* "the open sea", when sea food was not only more abundant but also more easily procured (Oliver 1974: 304). The seasonal nature of tuna fishing in eastern Polynesia has also been recorded for Hawaii (Goto 1986) and the Marquesas (Handy 1932). In prehistoric New Zealand, trolling for barracouta on the east coast of the South island was also a summer activity, taking place when seas were flat and windless conditions prevailed (Anderson 1981).

Access to the fishing grounds is a major factor in limiting tuna catches in parts of the Carolines (Gillet 1987: 17-18). As there is no real reef passage at Satawal, the sailing canoes can only go over the reef at high tide and the surf must be small. Wind conditions must also be favourable, in terms of strength and direction, for getting to the fishing grounds. However, as the fishing grounds are located in several different directions from Satawal, an unfavourable wind for one area may be desirable for another.

Strategies for offshore trolling for tuna utilise knowledge of fish behaviour to identify likely spots for schools to occur. Where comprehensive studies of tuna fishing have been undertaken in the past few decades it becomes clear that in these areas at least, although tuna fishing does contain an element of chance, this is considerably lessened by knowledge of tuna behaviour. Figures 26 and 27 show favoured tuna fishing areas in the Carolines, and Tokelau. Tuna are also known to aggregate around floating logs, and this information is utilised in strategies used in the Carolines (Gillet 1987). This is probably related to the habit of some small fish of hiding under logs, to confuse predators such as tuna which are looking up from below. The log

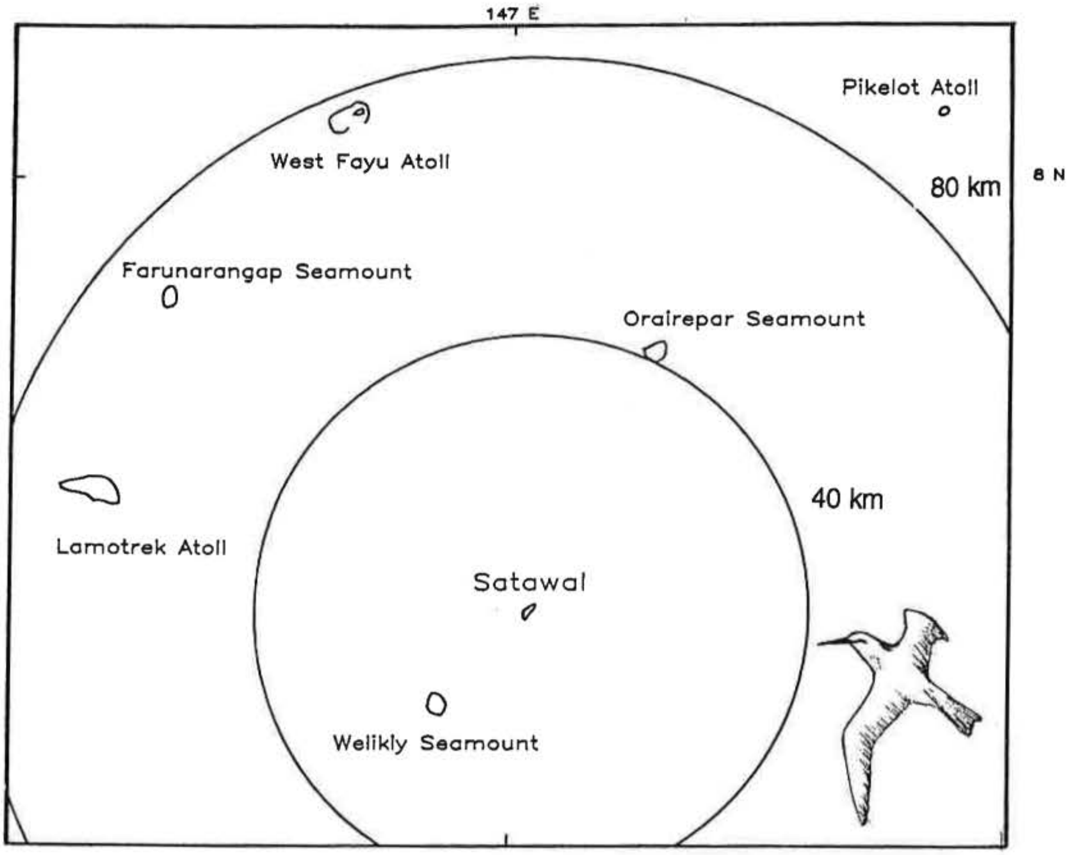


Figure 26: Seamount and island based fishing grounds in the vicinity of Satawal, Caroline Islands (from Gillet 1987: 17).

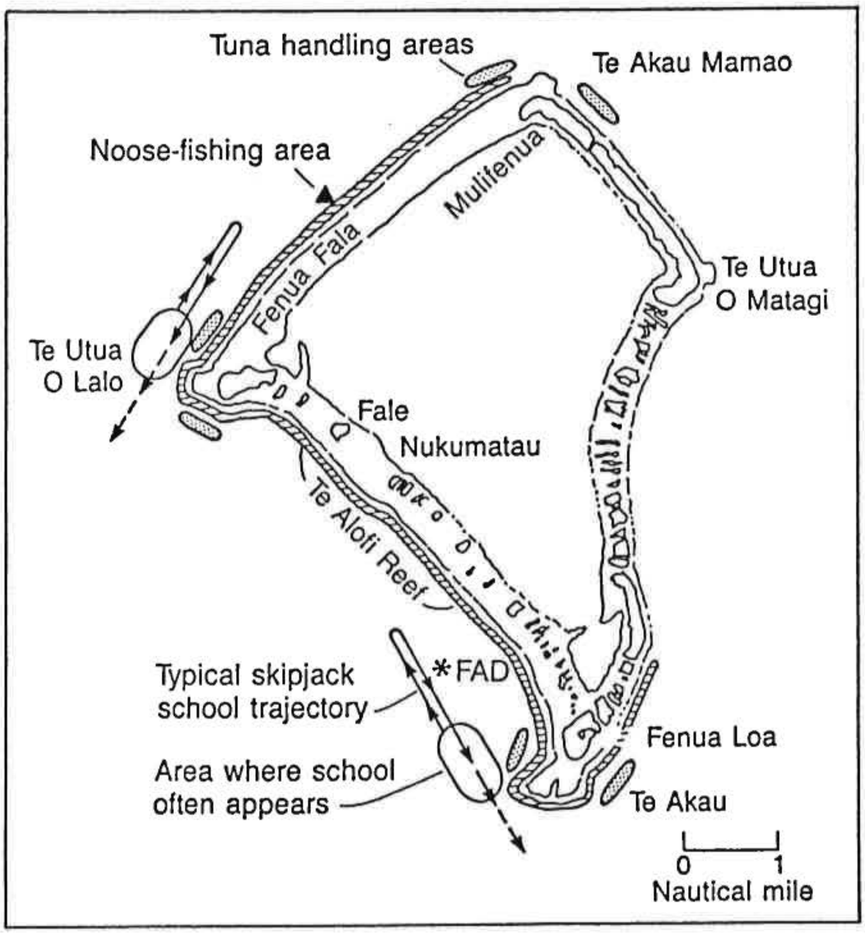


Figure 27: Fishing grounds in the vicinity of Fakaofo atoll, Tokelau (from Gillet 1985: 24).

represents safety for the small fish, as the shadow could be taken as an even larger predator by the predator below, and hence be avoided. A range of different types of tuna schools are also recognised in the Carolines and Tokelau, each with different behavioural characteristics important for deciding fishing strategies (Gillet 1985, 1987). Nonetheless, fishing for surface schools of tuna, particularly skipjack, involves wide areas of ocean being traversed. Te Rangi Hiroa (Buck 1930: 417) recounts that Bougainville, seeing a fleet of bonito canoes far out to sea, looked upon the Samoans as daring sailors and therefore called the island group the Navigator Isles.

Birds are also used to pinpoint the location of schools, and to inform on the behaviour of the fish they are associated with. Seabird flocks can be seen from thousands of meters, even in rough weather (Johannes 1981: 59). As well as following surface schools of fish, they can spot and follow schools below the surface which are invisible to the fishermen. It is important for fishermen to locate feeding schools, which are much more likely to take a lure. The main kinds of birds used by tuna fishermen in the Pacific include black and brown noddies, white terns, shearwaters and frigate birds (Johannes 1981, Gillet 1987, Kennedy 1930, Nordhoff 1930). The detailed knowledge provided by observation of bird behaviour is illustrated in the following excerpt, which describes an account given to Johannes by a Palauan fisherman:

> The most abundant seabird in Palau is the black noddy tern, *Anous minutus* (*bedaoch*). Flocks are commonly seen quartering back and forth a few feet above the surface in search of feeding schools of fish. If Ngiraklang sees them feed for a while, while moving fairly rapidly across the water, then fly quickly off a hundred yards and begin feeding again, he suspects that skipjack tuna, *Katsuwonus pelamis* (*katsuo*), are feeding beneath them. These fish move rapidly while diving and change direction frequently, surfacing to feed periodically. The deeper the fish dive the higher up the birds fly above them.
>
> In the presence of feeding yellowfin tuna (*tkuu* or *maguro*) *Thunnus albacares*, noddies behave much as they do over skipjacks. But yellowfin move somewhat slower than skipjack and change direction less frequently. This is reflected in the movements of the birds above them. Yellowfin also break the surface more forcefully and often than skipjack, frequently leaping completely clear of the water. Schools of yellowfin and the flocks of birds that follow them are often separated into several adjacent subgroups.
>
> A flock of noddies moving very slowly and steadily over water churned up more heavily than it would be by feeding skipjack signals the presence of kawa kawa, *Euthynnus affinus* (*soda*). Sometimes rainbow runners, *Elagatis bipinnulatus* (*desui*), travel in mixed schools with kawa kawa but seldom break the surface as they feed. (Johannes 1981: 60-61).

Trolling for tuna can involve a certain amount of trial and error. Once a school has been sighted and fishing begins, a range of lures of different shades may be tried before one which incites fish to bite is found. On Tokelau five different shades of pearl shell are recognised (Gillet 1985), while Nordhoff (1930) recorded an extensive body of knowledge from the

Societies, concerning not only characteristics of shell from particular areas, but variations in colour for each. Nordhoff (1930: 242) firmly stated his belief that fish instantly recognise the "correct" shell for weather conditions, time of day, and the small fish they are feeding on. Often, out of a range of lures, fish would strike at only one freely, although several may have been tried. In contradiction of this view, Johannes (1981: 122-123) argues, on the basis of the experiences of Palauan fishermen and marine biologists, that tuna are not so discerning. He observed that when skirts were ripped from worn commercial lures, Palauans customarily replaced them with skirts cut from plastic shopping bags. The colour may have been white, grey, pink, purple, green or blue, with varying amounts of black print. Palauans expressed little preference for one colour over another and stated that the fish seem similarly undiscriminating. This is related to the attractor principle mentioned earlier, where certain characteristics trigger instinctive behaviour in predatory fish. It is possible that the critical factor in the hackles is not the colour at all, but the projections themselves. They may signify the outstretched pectorals of a fish, or the important feature could be the air bubbles trapped in the hackles; this feature is not well understood, but the hackles do not represent a particular fish in the normal sense. Johannes (1981: 123) also cites experiments on lure material by a marine biologist, Ommaney, who comments "we never really found that one sort of lure was decisively better than any other. When the fishing was good any kind of lure would do as well as any other."

Hand-lining for tuna in deep water also incorporates knowledge of tuna behaviour. Three methods using baited one-piece hooks are currently still in use on Tokelau (Gillet 1985: 21). These techniques use a similar strategy to capture sub-surface tuna, and are focused at the locations shown in Figure 27. Hand-lining using a rock sinker and chum (*lulu*) is carried out at depths of between 30-100 fathoms. The target species is yellowfin tuna, other major species caught include bigeye and dogtooth tuna, albacore, wahoo, rainbow runner, billfish and sharks. *Faka poapoa* is shallow handling using chum, which is carried out in water 10-30 fathoms, closer to the reef and down current from the *lulu* areas. Major species caught are yellowfin, dogtooth tuna, wahoo and barracouta. *Fakatu*, or deep hand-lining, takes place in water 80-100 fathoms, and about 150 metres seaward of the *lulu* spots. Although the species targeted by this method are sharks; yellowfin, albacore, bigeye and dogtooth tuna make up a significant part of the catch. Each of the hand-lining areas shown in Figure 27 is close to a point of the atoll. On days favourable for this kind of fishing, the current flows along the coast towards a point. The fishermen believe that tuna approach these points from offshore, swimming against the current in search of food. The hand-lining areas are situated up-current from the points, so that a fish, following chum or odours from bait in the course of their normal path, will arrive at the fishing gear.

On Kapingamarangi, hand-lining at depths also enables fishermen to fish for tuna which are not at the surface and thus susceptible to a trolled lure. This strategy is one which is associated with a great deal of ritual and economic significance on the atoll (Lieber 1994: 108). The tuna canoes are named *waga madaligi*, which is a metaphor both for the canoes themselves, and also the calm season when this activity takes place, which is marked by the appearance of the constellation of the Pleiades in the night sky. In the past, in the Society Islands, the presence of the Pleiades may have also been a factor in the commencement of the tuna season (Nordhoff 1930: 238). On Kapingamarangi, the canoes initially try to locate the tuna school by chumming with minnows or flying fish at a depth of about 30 to 40 fathoms. They spread out 180 to 270 meters apart, each getting one or two tuna as the school passes in a line. Subsequently the chum is taken down to 50 or 60 fathoms, with the canoes forming a rough circle. They try to keep the tuna circling at this depth taking the chum and bait, so a uniform line length is very important. At this point catches of up to 15 to 30 tuna per canoe can be achieved. The tuna return to the same spot daily until they leave the atoll.

In a broader sense, the individual strategies described above are not practised independently of the others. An over-arching factor of any strategy for tuna fishing allows for the seemingly fickle nature of these fish. On Tokelau, for example, no one strategy is used to the exclusion of the others. A pole and line is taken out on every trip on the open sea, while different methods may be carried out simultaneously in the same canoe by different men (Gillet 1985). Nordhoff (1930) also reported that when going *tira* fishing the crew also took along their bonito rods, in case they came across a school of surface feeding fish. By using a range of methods, the chances of having a successful trip are increased.

The archaeological dimension of tuna fishing

Two broad approaches towards the archaeological study of fishing can be identified in the Pacific, those based on artefactual studies, and analyses which are based on fish remains recovered from sites. These approaches are not mutually exclusive and arguments for fishing strategies in archaeological contexts usually incorporate material culture as well as faunal remains. Although artefactual studies have generally been designed to trace cultural relationships, Reinman (1970) investigated fish-hook technology and the relationship between certain fish-hook characteristics and their role in fishing strategies, while Allen (1996), Goto (1986) and Davidson and Leach (1996) have considered the relationship between form and function in fish-hooks.

The analysis of fish remains from sites forms the basis of many archaeological investigations into fishing behaviour in the Pacific. Although researchers need to be aware of possible taphonomic, excavation or analytical bias introduced into results, this approach provides a record of fish actually caught. In conjunction with fish remains in sites, researchers have also used ecological information, ethnographic evidence and fishing gear recovered from sites to reconstruct fishing behaviour. These sources of information also have their own limitations: ethnohistoric evidence may not cover the full range of fishing methods used, while fishing gear from sites may also not be representative of all methods used. Davidson and Leach (1996) explored various kinds of evidence about past fishing behaviour on Nukuoro Atoll, including ethnographic information and archaeological assemblages of fish-hooks and fish bone. They concluded that "Although we may claim to have produced a richer picture from these various lines of evidence, it is not a coherent and consistent picture. This reinforces our view that each kind of evidence must be explored within its own parameters." (Davidson and Leach 1996: 201).

Ecological information can inform on the relationship between fish behaviour and fishing strategies, which is reflected in the development of particular methods intended to catch certain fish. Butler (1994) examined the relationship between fishing technology and fish feeding behaviour as part of an investigation into Lapita fishing strategies. She linked ethnographically attested capture techniques with fish feeding behaviour. Inherent properties of fish physiology suggest the kinds of technology most capable of catching them. Butler classified fish as either herbivorous/omnivorous or carnivorous, based on their feeding behaviour and locomotion. Small mouthed herbivores such as surgeon fish or parrotfish are not attracted to active prey and are hence less likely to bite at a baited hook than carnivorous fishes. They also swim relatively slowly, and thus are easier targets for nets, spears and poisons. Conversely, fast swimming carnivores such as tuna are be attracted to hooks, lures and baited traps.

Fishing strategies in the Pacific tend to be differentiated predominantly by the kind of technology used. For example, in Palau, Masse (1986) assigns fish (by family) to seven methods: bait hook, trolling lure, net, hand spear, weir, basket trap, or other. Green (1986) assigns fish from the SE-RF-2 Lapita site in the Solomons to four categories: trapping/netting, angling, spearing and poisoning. Leach *et al.* (1988) define eight likely catch methods: netting, demersal baited hook, pelagic lures, harpoons or bait trolling, general foraging, basket traps, opportunistic, and no strong opinion for fish from the Mochong site, Micronesia. Within these reconstructions fish are assigned to a "preferred", "common" or "probable" fishing method. This approach recognises that while fish can be assigned to a particular method on the basis of the information available, the probability exists that some were also caught by other methods as well. Masse (1986: 100) also points out that using fish families in these types of reconstruction can be problematic. Some fish families, for example, the wrasse (Labridae) family, contain large numbers of different genera and species with a wide range of habitats and adaptations. While many wrasses are solitary, carnivorous and hence readily take a baited hook, some species school and are hence susceptible to nets. Also, porcupine fish are carnivorous and will take a hook, but their mouths are so small that unless a special hook is used, netting is more likely. Within these kinds of reconstruction the most likely method given for tuna remains in sites is trolling.

Ethnoarchaeological reconstructions of fishing strategies incorporate specific information about the local marine environment, along with modern fishing practices to generate a model of contemporary fishing strategies. Archaeological fishing strategies are reconstructed from a comparison of this model with archaeological evidence such as fish remains and material culture (Kirch and Dye 1979, Rolett 1989, Walter 1991). This kind of approach has highlighted the relationship that exists between the marine environment and fishing technology and behaviour. The marine environment is classified into a series of distinct areas or "zones" (see Kirch and Dye 1979, Reinman 1967, Rolett 1989, and Walter 1991). These zones, the reef flat, reef edge, lagoon and open sea (see Figure 28), are structured around both fish ecology and human usage of the sea. Such classifications often take into account the way local Pacific Island people view their environment. Each zone is associated with a range of particular fishes, and a variety of methods and strategies most appropriate for their capture. Within these general schema there is obviously considerable variation between islands in the Pacific.

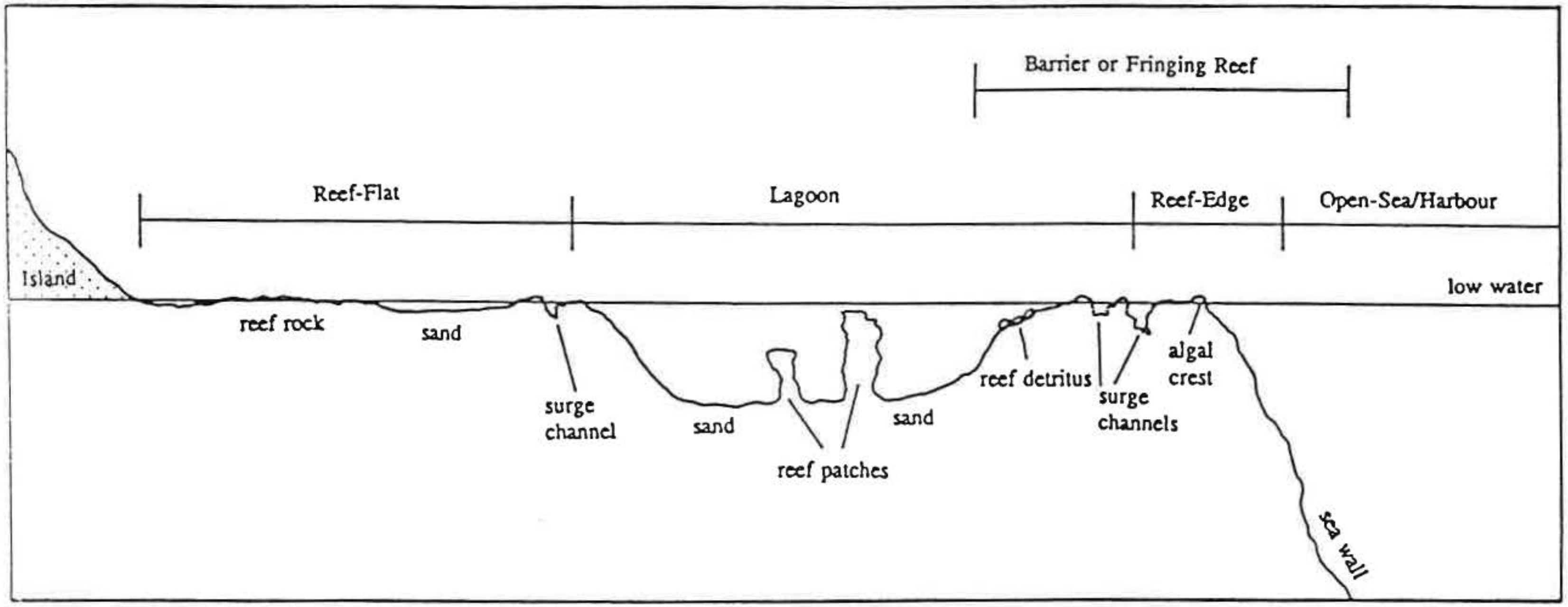


Figure 28: Generalised profile of Pacific island marine environments (from Chatan 1992: 25).

Within these divisions of the marine environment, tuna are usually associated with the open sea zone. Surface schools are highly likely to have been taken with a trolled lure, although the use of hooks for trolling has also been documented (Davidson and Leach 1996). Other strategies such as hand-lining are also possible for sub-surface tuna. However, these are more difficult to determine archaeologically, given the wider range of species also taken using one-piece hooks. Tuna may also venture into lagoons and close inshore during spawning aggregations, when they would be susceptible to nets.

The relationship between the fishing technology and tuna in sites is a difficult one to establish. It becomes particularly relevant for the reconstruction of fishing strategies. The presence of fishing gear in sites is obviously indicative of the kinds of fishing methods and strategies people may have been practising. Yet the fishing gear from sites may not represent the full range of methods used, given the differential preservation of fishing gear.

To begin with, lures are not necessarily used only for tuna fishing. Several other kinds of fish will take a lure trolled on the surface. These include other pelagic predators such as jack fish (Carangidae) and sharks (Dye 1983, Davidson and Leach 1996: 9). The Tobi islanders from Palau use a smaller lure for smaller, near reef species (Johannes 1981: 123). A range of sizes and types of lures targeting different fish have also been documented from the Solomons (Kaschko 1976), and Samoa (Buck 1930). On Pukapuka, as well as being used for jacks, small composite hooks were used to catch squirrelfish (Holocentridae) (Beaglehole and Beaglehole 1938). Lure size may therefore be indicative of the kind of fish being targeted.

It is also likely that some ethnographic examples of lures may have been made for trade with Europeans. Many of the lures, particularly those attributed to Tonga, held in museum collections are extremely large, and do not appear to have ever been used. Nordhoff (1930: 245) comments that many lures he has observed in museums were constructed in such a way as to make them ineffective for actually catching fish.

Variation in lashing method and points from trolling lures has been identified ethnographically throughout the Pacific (Anell 1955, Burrows 1970). In Melanesia (with the exception of the Solomon Islands) and eastern Micronesia the line is characteristically attached only to the shank head. Polynesian lures typically have the line attached to both the head of the shank, and the base of the point. This type of attachment is also found in the Solomons and the central and western Caroline Islands (Gillet 1987: 14). Polynesian lures are further differentiated according to the shape of the point where it is lashed to the shank. Burrows' (1970: 14-15) study in cultural differentiation in Western Polynesia distinguished between the "bonito hooks" of Western Polynesia and those of the rest of Polynesia. He divided the lures into several subtypes (Figure 29), and concluded that of these only one (3a) is found in Western Polynesia. This subtype has a proximal projection, and is pierced with two or three holes for lashing. Lures which have no projection, or a distal projection, are considered to be characteristic of central and marginal Polynesia. Lures with a characteristically West Polynesia points have however been found in early archaeological contexts in eastern Polynesia, including Hawaii, the Marquesas, New Zealand and Tahiti (Sinoto 1967, 1970).

The distribution and variation between trolling lures, particularly points, has been used in the Pacific region to address culture historical questions about the movement and relationships between groups of people (for example Bellwood 1970, Sinoto 1970). The typologies which have been constructed within the culture historical context use stylistic, as opposed to functional, attributes. Possible functional correlates of shape and size may provide other kinds of information. For example, the kind of lashing found on Polynesian hooks appears to have developed to transfer the weight of a hooked fish from the shank to the line. This kind of attachment means lures are less likely to break, resulting in an increase in successful fishing landings, and less damage and loss of valuable equipment. Point length and sharpness are also related to the experience and skill of the fisherman. An inexperienced fisherman uses sharp and long points to ensure retaining any fish-hooked, while the more a skilful fishermen will have shorter, blunt points to enable the easy unhooking of fish (Nordhoff 1930). On Satawal, the skill of the fisherman also determines the angle between the hook and its base (Gillet 1987: 14). For a novice, the angle is very acute to lessen the chance that a tuna will prematurely dislodge after hooking. An expert uses a hook with a more obtuse angle to facilitate rapid unhooking, thereby increasing the capture rate.

The absence of lures in archaeological sites where relatively high numbers of tuna have been identified may be due to a number of reasons. The possibility exists that tuna were being caught using other kinds of methods. Although it appears that skipjack are normally only taken by trolling, several other methods using different technology have been identified for catching tuna in the Pacific. Unfortunately intra-family level identifications are not yet made for members of the Scombridae family, which could provide further information on this question.

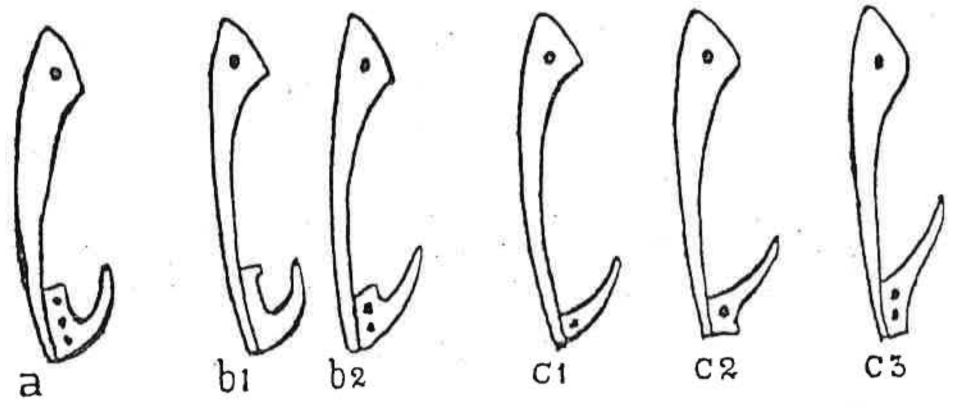


Figure 29: Types of two piece lures, showing different forms of point, from Burrows (1970: 12). a: western, with proximal projection. b: intermediate 1. proximal projection (Tuamotus) 2. slight proximal projection (Fanning Islands) c: central-marginal 1. simple point (Hawaii) 2. distal projection, one hole (Society Islands) 3. distal projection, two holes (Marquesas).

Other explanations for a scarcity or lack of lures in sites include the preservation and survival rates of trolling gear, and people's attitudes towards this kind of equipment.

Kaschko (1976) collected information on the fishing gear used on Uki, Solomon Islands, from a local fisherman, then compared this with the fishing gear recovered from Su`ena, an archaeological site on the island. He found an almost complete lack of most of the set of ethnographically known fish-hooks in the archaeological assemblage from Su`ena. As most of the hooks known ethnographically were made from durable materials he was unable to attribute their lack to a failure in preservation. Archaeological fishing gear was rare, except for stone sinkers, and to a lesser extent, lure points. Kaschko argues that the explanation for this lies in the amount of energy expended in the production of fish-hooks and the value placed on them. He comments:

> It takes a good deal to produce most of the fishhooks, and they are highly valued. When a fishhook is broken, if possible it will be reworked and used again rather than being discarded. A broken *ta`i* [one-piece casting lure] may be reworked to make a *hahara`a* [shank] for a *ta`i hinou* [two-piece lure]. Sometimes a broken lure may even be saved to use as a pattern for making a new hook. And good fishhooks often last a long time and may even be passed down through generations. (Kaschko 1976: 200).

This is supported by evidence from Tokelau (Gillet 1985). Lures are valuable pieces of equipment, especially those which work well, and fishermen try hard not to lose them. This includes restricting the fish pursued to those of a particular size. Fish which are too big increase the likelihood of lines breaking and hence the loss of lures. In environments where pearl shell is scare the loss of lures would be even more serious.

Summary

Several methods for catching tuna have been identified, including trolling lures, one-piece hooks and nets and sweeps. These are summarised in Table 1. Strategies which use these methods take into account a range of factors in order to maximise success. These include taking advantage of the seasonal behaviour of tuna in parts of the Pacific, technological requirements, and use of environmental knowledge.

While contemporary accounts describe a range of methods and strategies used to catch tuna and the catch itself, most ethnographic works tend to focus on descriptions of the equipment used for "bonito" fishing. This makes it difficult to consider the time depth for some of the methods recorded for taking sub-surface tuna, and also how successful methods actually were. In an archaeological context, reconstructions of fishing strategies usually categorise tuna as an open-sea species, most likely to be taken with a lure.

The range of possible methods identified to catch tuna include some which may not be clearly indicated by fishing gear in archaeological sites. The correlation between technology present in sites and the strategies used is not a simple one. Relatively high numbers of tuna in sites are considered indicative of a strategy designed specifically to take tuna, or perhaps tuna and fish which have similar behaviour.

Table 1: Summary of methods for catching tuna.

Island group:	Trolling with lure	Trolling with one-piece hook:	Baited hook:	Netting:
Hawaii [1]	•		•	
Tahiti [2]	•		•	
Samoa [3]	•			
Ellice Islands [4]	•			
Tokelau [5]	•		•	
Satawal [6]	•			
Kapingamarangi [7]	•			
Nukuoro [8]		•		
Papa New Guinea (Motu people) [9]				•
Solomon Islands (Uki) [10]	•			
Ponape/Truk [11]				•

Sources:

(1) Iversen *et al.* 1990
(2) Nordhoff 1930
(3) Buck 1930
(4) Kennedy 1930
(5) Gillet 1985
(6) Gillet 1987
(7) Leiber 1994
(8) Davidson and Leach 1996
(9) Pulsford 1975
(11) Kaschko 1976
(11) Severance 1986.)

4: Social aspects of tuna and fishing for tuna in the Pacific

In a broad sense the aim of this research is to gain a better understanding of tuna fishing in Pacific prehistory. The major focus in the understanding of this activity is through archaeological sources of information, particularly faunal remains. However, fish and fishing behaviour include a sociocultural dimension which requires consideration. In attempting to do so such a study moves outside the fundamental levels of analysis of archaeological fish bone, which initially informs on the quantity of fish remains, and kinds of fish, present in sites. The following translation by Handy (1932) of Moerenhout's observations from the Society Islands serves to highlight the cultural significance of tuna fishing which is alluded to in much of the ethnohistoric literature. Consideration of both the social and economic significance of tuna fishing are important if the role of this activity is to be understood within the context of Pacific prehistory.

> When, in the months of November and December, which were called *te tai* (season of the outside or of the sea), the bonito or scomber season opened, but a single canoe was allowed to go out and fish, and its entire catch was dedicated to the gods. This day was also tapu, that is to say, sacred. No one was allowed to approach the sea-shore, to make fire, to cook food, nor partake in food before sunset. Nor could canoes or houses be built, or cloth manufactured, or mats or nets woven. In a word, all work was prohibited, and it was a day of silence and devotion.
>
> While the fishermen were away, the priests applied themselves to praying at the temples; and their assistants were busy, in the principal marae, cleaning it up, decorating it with green branches, in dressing an altar for the first fishes caught. When the canoe returned in the evening, it lay in the water near the beach, awaiting the arrival of the priests. After some prayers and other ceremonial these allowed the fishermen to land and to bring to them the days catch, which, whatever it was, had to be carried in *toto* to the marae. There, after more prayers, two or three of the largest fish were placed on the altar, and the others were entirely consumed (?burned) on a fire that burned before the altar (on les consumait tous et entierement, sur un bresier allume devant l'autel).
>
> This first day's catch was for the gods; that of the second day was for the Arii, or chief; and it was only on the third day that the fishing was open to everyone, and anyone who desired could go fishing. (Handy 1932: 78).

This chapter begins with a review of the ethnographic information about tuna fishing in the Pacific, and considers its usefulness for investigating the sociocultural context of this activity. Then, based on ethnohistoric and contemporary accounts, possible social and cultural correlates of tuna fishing will be discussed. The focus will be on two main aspects involved in this activity: ritual rules and beliefs, and the relationship between tuna fishing and social structure.

About tuna fishing in Pacific ethnographic literature

Ethnographic accounts have been used extensively in Pacific prehistory in the investigation of past fishing practices. In conjunction with faunal analyses and material culture, ethnographic observations often form the basis of archaeological reconstructions of fishing behaviour. These records span a significant period of time in terms of cultural change in this region, beginning with the observations of early European explorers, traders and missionaries in the 18th and 19th centuries. These are followed by ethnographic accounts from the early to mid 20th century, written at a time when many cultures had already undergone major transformations as a result of European contact. Finally, contemporary works often investigate the effects of colonisation, decolonisation and the processes of change involved. As a source of information contemporary and historic ethnographic accounts provide a wealth of material about fishing in the Pacific. However, their relationship to any subsequent archaeological interpretation or explanation of past human behaviour needs to be made explicit. Furthermore, the viewpoint of the observer and the context of the observations need to be considered when using these accounts to provide an insight into the cultures they describe.

Many of the ethnographic works about Pacific island cultures produced in the early 20th century have drawn criticism for the inherent bias of the ethnographers. Ethnographic accounts of fishing seldom cover the full range of methods used, tending to concentrate on the more spectacular activities, such as tuna fishing, to the exclusion of less exciting but more reliable pursuits (Leach and Davidson 1988: 3). A failure to recognise the importance of inshore shallow water reef fishes resulted in a selective reconstruction of the subsistence economies of some areas (Fleming 1986: 17). Furthermore, a focus on the material culture associated with specific fishing activities has resulted in a lack of information about what kinds of fish were caught (Dye 1983: 242). Early ethnographers also wrote very little about women. Women and their activities, including fishing, were often marginalised or ignored (Chapman 1987, O'Brien and Tiffany 1984). This was likely in part to have been a consequence of male ethnographers having greater access to male informants; also, men in Pacific island cultures are known to minimise the importance of women's contribution to fishing (Chapman 1987: 280, Mathews 1993: 29, Kirch and Dye 1979: 29). The use of terms such as 'fishermen' further obscures the articulation of gender roles involved in fishing practices.

At the time of these accounts, major changes were also occurring in areas relevant to this study, including the nature of the subsistence economies of the islands, and the organisation of household labour and gender relations. By the time Nordhoff wrote his account of offshore fishing in Tahiti (1930: 10), only two of the five methods he described were still of any economic importance. When Bataille-Benguigui (1988) undertook her study of fishing in Tonga 63% of the population, previously composed mostly of fishermen, were farmers. Those in marine occupations only consisted of 7.3%. This shift is attributed to changes to the economy introduced by monetarisation and the impact of Western society (Bataille-Benguigui 1988: 187).

Fishing for skipjack with pearl shell lures had retained its importance in Tokelau until shortly before Gillet (1987) undertook his study of tuna fishing. Nevertheless, although it had been 10 years since tuna had been caught using authentic poling techniques, the fishermen he interviewed wished to speak most about this method. The possibility also exists that the ascription of importance to tuna fishing was as much a function of the informant, as of the ethnographer. Leach and Davidson (1988: 2) point out in their discussion of fishing on Nukuoro and Kapingamarangi that there is a difference between what people say and what actually occurs, this is particularly the case regarding the "fishy story". On these islands there are numerous chants about the rainbow runner, and to the casual observer this fish would appear to be the most sought after and perhaps most frequently caught. However, remains of these fish were infrequently found in archaeological sites.

In the Pacific, fishing, or more specifically male dominated types of offshore fishing, are often defined as 'hunting'. 'Hunting and gathering' is considered an appropriate description of marine exploitation in the Pacific by Kirch and Dye (1979: 53). They comment that "anyone who has participated in a Polynesian fishing expedition will realise that fishing is by no means a passive activity; the excitement of the chase is just as fully expressed as among the more often cited land based hunters". Based on archaeological evidence the people of Fa`ahia in French Polynesia are characterised by Leach *et al.* (1984: 195) as "an adventurous group, highly successful at harvesting marine resources, and in particular the fast swimming larger species, demanding a specialised "hunting" approach to their environment". When reporting on the perceived attitudes of Pacific island people towards offshore fishing researchers from outside the region are of course influenced by their own cultural context. Classifying this activity as hunting has implications based on European notions of hunting, which may or may not translate well in terms of Pacific island definitions. A good example of an observation by an indigenous Micronesian is the comment by Fleming (1986: 1). He states that he deliberately uses the term "hunted" in a number of places throughout his thesis, in preference to "caught". He argues that this term better connotes the mental attitude which Pacific islanders adopt towards marine *prey* [my emphasis] during their fishing activities. He believes "caught" is a somewhat neutral western European concept which is more appropriate to the mass harvesting of marine resources. It is apparent that offshore fishing is conceptualised differently to other forms of fishing, both by local people and researchers in the Pacific.

The involvement of women in tuna fishing is difficult to ascertain, particularly given the range of roles of women in fishing across the Pacific and also the changes in the region following contact with European cultures. A pervasive belief held is that women's participation in fishing is limited to 'gathering' or foraging in shallow waters using only the most basic of equipment. An important element of this belief is the limited nature of the equipment used by women. However, studies of women and fishing have demonstrated that their participation in fishing activities varies considerably throughout the Pacific (Chapman 1987, Matthews 1993). While reef gleaning is an activity of women and children, women may also use a wide range of techniques for fishing on the reef including nets, traps, and hook and line. Fishing beyond the reef is, however, rarely undertaken by women anywhere in the Pacific. Chapman (1987: 268) reports that where this does take place, fishing for bonito, tuna and turtle tends to be restricted to men. Women's fishing also tends to be more secular than men's, lacking the rituals and magic often involved in aspects of men's fishing (Matthews 1993: 3). Restrictions placed on women's mobility and the gender specific nature of offshore fishing make women's participation in tuna fishing uncommon in the Pacific. Interestingly, Nordhoff's influential descriptions of offshore fishing in the Society Islands includes a reference to women participating in a fishing expedition for albacore, including baiting the hooks (1930: 151-153).

Recent developments in archaeology have seen archaeologists undertake their own research in contemporary societies in order to understand aspects of human behaviour resulting in the formation of the archaeological record. In the Pacific region this has included studies of fishing and shellfishing (Dye 1983, Walter 1991, Kirch and Dye 1979, Marshall 1987, Rolett 1989) and birding (Weisler and Gargett 1993). In conjunction with such studies, archaeologists can develop models to explain past behaviour which can then be evaluated against the archaeological data. The focus of these types of studies have, however, been directed towards economic and ecological aspects of fishing, rather than its cultural significance.

Often apparent in the use of ethnography in Pacific archaeology is an assumption of some kind of continuity between past and present populations (Davidson 1988: 20, Kirch and Dye 1979: 73). Although the issue of continuity has been stressed in ethnoarchaeological studies in the region, recognition of temporal variability during this time is also important. This is particularly so when considering fishing practices. For example, the introduction of the Nukuoro style of sailing canoe to Kapingamarangi in the 1920's accompanied the arrival of new fishing strategies including trolling under sail, which largely replaced bonito pole and line fishing (Lieber 1994: 149). The influence of European technology and equipment has also influenced fishing strategies. On Ma'uke, in the Cook Islands, the adoption of modern diving equipment (face masks, fins and spear guns) and techniques, that are less time consuming and labour intensive compared to maintaining and operating canoes, has resulted in a change in fishing methods (Walter 1991: 56). Although the changes in technology are extreme, the new techniques are aimed at a similar range of species to those taken by more traditional methods.

Overall, as a specialised, culturally important, highly visible and predominantly male activity, descriptions of tuna fishing fit well within characterisations of life in Pacific island communities as provided by historical ethnographic accounts. Many works, particularly those from Polynesia, contain detailed descriptions of tuna expeditions and the technology associated with this activity. Some also allude to the significance of tuna and tuna fishing in the community, both in terms of economics and the importance of tuna in various aspects of social life. More recent studies of fishing in the Pacific also include observations about the changing context of this activity. Given the cultural importance accorded to this activity, by both Pacific peoples and researchers alike, ethnographic accounts provide a means of investigating social aspects of tuna fishing.

Social dimensions of tuna fishing

The following discussion focuses on areas where tuna and tuna fishing are of significance in terms of social activity. These include ritual rules and beliefs, and the relationship between fishing and social structure. Notwithstanding these aspects, tuna fishing is also an exhilarating experience, greatly enjoyed by the participants. Even when catches are poor in Satawal, and hardly justify a trip in terms of food value, there are no shortages of crews. "Loss of sleep, bone chilling rain, baking sun, and hours of monotonous transit to and from the fishing ground aboard a pitching, rolling, jerking canoe are considered small sacrifices for the thrill of poling tuna" (Gillet 1987: 6). The fishing activities involved are those which target aggregations of fish and are hence likely to result in relatively large catches when successful, as opposed to single, and opportunistic catches. It is not intended to provide an exhaustive account from the numerous sources of information available, but to highlight the range of possible social correlates of this activity as attested by ethnographic sources.

Ritual rules and beliefs

Fishing continues to be an important daily activity in many parts of the Pacific, however, it is clear that some fishing activities are regarded differently to others. Specialised activities such as tuna and shark fishing often require the performance of specific, often elaborate and ritualised, behaviours. These activities usually take place beyond the reef, on the open sea, which is an environment associated with danger and uncertainty. Ritualised behaviour occurs in many different contexts: preparations, ceremonies and prohibitions prior to fishing trips, and the actual behaviour during fishing and what follows at the conclusion of the activity.

On Kapingamarangi, the canoes used for tuna fishing were known as *waga madaligi*, the canoe of the Pleiades (Lieber 1994: 107-108). The Pleiades is the constellation which is the metaphor for the calm season and also the metaphor for the tuna canoes. In the past, once these canoes went out no other fishing in a canoe was permitted. The number of canoes which went out depended on the number of old men available who 'knew' the appropriate chants to the gods. Crews were established at the start of the season and remained intact throughout, and were under strict taboos on food and sexual activity. When the canoes were retired by the high priest at the end of the season other canoes could fish for tuna, but were restricted as to the number they could catch each day.

On Satawal, in the Caroline Islands, magic continues to be performed in conjunction with tuna fishing activities. Gillet (1987: 27-30) comments that despite the general opinion of fishermen that very little magic is associated with tuna fishing as compared to the past, it was surprising how much was actually being performed. This included magic to affect the sea condition and weather, to attract logs which act as fish aggregation devices, and to divine the catch rate and safety of the canoe. Also observed were various prohibitions, or requirements to perform particular activities. Ackimichi (1986: 19) also describes magic practised on Satawal 'to call fish' including tuna to the island. As tuna and skipjack were regarded as sacred, use of their ordinary name was often prohibited so other names were used instead. It is believed that violation of this rule could result in the eventual disappearance of the fish.

Tuna fishing by the Motu people of Papua New Guinea is associated with ritual behaviour (Figure 30), although the ceremonies attached to this seasonal activity are increasingly losing their significance (Pulsford 1975). Tuna are caught by nets from canoes, stationed across marked channels in Oyster Bay. Following the first successful catch a magic ceremony is conducted to call the tuna to the bay. During the fishing season various rules must be adhered to; for example, the tuna are handled very carefully, if one is knocked against the side of the canoe the perpetrator must kneel and kiss the fish, or else it is believed no more will enter the nets on that day. If the fish do not enter the nets, the men become worried as they believe the reason is based on their personal behaviour. The tuna are considered to know everything that goes on in the village; broken household taboos, anger, stealing, adultery or failure to meet obligations can all result in fish avoiding the nets. Tuna are believed to be the offspring of ancestors of those in the community; this relationship, the necessary rituals and the reason for the sacred tuna season are recounted in a myth.

Sometimes not only the fishermen but also those left behind are constrained to behave in a particular manner. In Tonga, a failure at sea when all material and meteorological circumstances indicate success can be attributed to two possible causes: a death in the extended family of the fisherman or the aberrant behaviour (according to either traditional or Christian criteria) of someone in the village. This could be robbery, adultery, transgression of taboos or illegal access to land (Bataille-Benguigui 1988: 188). In most of East Polynesia, the household must be quiet when a household member is fishing at sea, and the rules can be quite strict at times (Richard Walter pers. com.). Nordhoff (1930: 251) writing in the Society Islands, observed that strict chastity was required of wives, daughters and girlfriends while bonito-fishermen were out at sea. A breach of this rule was believed to bring bad luck or even disaster to the fishermen. When a bonito was hooked through the lower jaw, an unusual occurrence, it was taken as a sign that someone ashore was not behaving as they should. It was also thought that if a man disputed with his wife before putting out to sea he would catch no fish.

Figure 30: Tuna fishing by the Motu people; the first catch each day is fastened to a pole and ceremonially carried to the village (from Pulsford 1975).

The majority of ritual behaviour appears, therefore, to be undertaken to ensure that fishing expeditions are successful, and that the fish continue to come to the fishing grounds. Success includes not only good catches but fair weather and the safety of the members of the expedition. Generally ritual behaviour appears to take two forms. Firstly, using magic and petitions to supernatural forces to facilitate the desired outcome, and secondly, through the observance of prohibitions on the behaviour of both the fishermen, and the people left behind. The ritual rules associated with tuna fishing also serve to reinforce general codes of behaviour; poor fish catches can be attributed to failures in the observance of these codes.

However, in reviewing the literature which describes this kind of behaviour it becomes clear that the stringency with which some of these kinds of behaviours are adhered to has changed markedly during the historic period. For example, on Kapingamarangi tuna fishing retained its traditional form and technology until 1917, although western style line and hooks were being used for other forms of fishing. Lieber explains:

> By then Kapinga [sic] were using and coveting European fishing gear, but they rejected metal hooks for tuna and bonito fishing for fear of angering the gods. Not until conversion to Christianity did the 'canoe of the Pleiades' lose its integrity as a sacred endeavour. Kapinga were convinced of the superiority of metal hooks by 1910, but there was more at stake in tuna fishing than mere technical efficiency. Kapinga did not maintain the integrity of tuna canoes and their technology out of a sense of nostalgia or sentimentality or inertia, but rather for purely pragmatic reasons—its sanctity was part of what ensured its success. Once they were convinced that this was not true, they abandoned the ritual constraints on tuna fishing without regret. (Lieber 1994: 108)

A functional explanation for the significance of rituals and prohibitions associated with fishing has been put forward by Malinowski (1954). He argues that rituals are a form of magic, carried out by people to assuage their anxiety in a world they cannot fully understand. The performance of rituals allows people to regain confidence and assurance, and to hope for aid, protection and success (Malinowski 1954: 140). When the efficacy of these rituals is repudiated, as on Kapingamarangi, they lose their importance. In the Caroline Islands, some items of tabu associated with tuna fishing are still strictly observed, however, many are now disregarded (Gillet 1987: 29). The general attitude expressed to Gillet by people, even the older navigators, was a sense of relief at getting rid of bothersome customs. The influence of the Catholic Church was usually cited as the cause of the change.

Bataille-Benguigui (1988: 193-195) disagrees with the appropriateness of Malinowski's theory to explain much of the ritual behaviour associated with fishing she observed in Tonga. Rituals were performed for fishing in shallow water with little apparent risk (although they may have related to ensuring good catches), the participants in fishing rites did not at any time assume the gestures or powers of magicians or sorcerers and some highly dangerous fishing techniques took place without any accompanying ritual behaviour at all. She argues that the arrival of the fish, and the ritual aspects involved in fishing and redistribution act to reinforce the traditional village hierarchy, and maintain social balance. It is possible, however, that the performance of fishing rituals incorporates both Malinowski's theory and also contributes to aspects of social organisation.

Fishing and social structure

Offshore fishing has had an important role in reinforcing social organisation, and in both determining and identifying prestige and social status in many Pacific island communities. The social values associated with tuna fishing operate on both an individual and community level. On one hand, individual fishermen may acquire status through their demonstration of skill, success and courage in the pursuit of these fish. On the other hand, while high ranking members of the community may also acquire social status on these terms, their position in the community is also indicated through their control of the activity, and of the results of offshore fishing expeditions.

The knowledge accumulated over a lifetime of tuna fishing is highly valued and the possessor of such is respected for this. A successful fisherman on Tikopia was known as *tangata o atu,* man of bonito, and was entitled to stand up his rod at the stern of his canoe as he came into shore as a symbol of his skill, to the general admiration of onlookers (Firth and Firth 1991: 406). On Kapingamarangi, the prestige accorded to deep sea fishermen was proportional to the dangers they faced and the responsibility they carried for the livelihood of others (Lieber 1994: 193). In East Polynesia, tuna fishing was considered to be a pursuit of the high ranking (Oliver 1974: 281-282, Titcomb 1974: 4). It provided an enjoyable sporting activity and an opportunity to demonstrate physical prowess.

In many cases, the tuna catch is distributed throughout the community; therefore every member has a stake in the success of the enterprise and the skill of the fishermen. On Tokelau, the system of *inati* (institutionalised sharing) ensures that every member of the village is allotted an equal portion of certain resources (Huntsman and Hooper 1996: 76-83). *Ika ha* (sacred fish) which include turtles, swordfish and marlin, skipjack and *o*, the baitfish on which skipjack specifically feed, are distributed according to the *inati* principle. Figure 31 shows a village divider laying out portions from a skipjack catch.

The control over resources such as tuna and activities such as offshore fishing may also be indicators and act to reinforce political and religious hierarchies within a community. This may be demonstrated on several levels, from the redistribution of the catch, to the possession of the technology required, or control over access to offshore waters. Te Rangi Hiroa (Buck 1930: 124) observes that in Samoa bonito are regarded as a "chief's fish", and that a set division and allocation had become established. The ceremonial divisions are shown in Figure 32. Handy (1923: 167-168) describes the distribution of the catch from fishing expeditions in the Marquesas as taking place either on the shore, or more formally before the chief's house. In Satawal, if more fish are caught than the crew requires, the excess is also deposited in front of the chief's house for redistribution (Gillet 1987: 29).

Restrictions on fishing activities are often a feature of historical accounts from East Polynesia (see Handy 1932 (Marquesas), Nordhoff 1930 (Tahiti), Titcomb 1977 (Hawaii)). Two types of restrictions on fishing activity were identified by Oliver (1974: 311) in pre-European Tahitian society. Firstly, limitations placed by the owners on fishing in any specific places which they controlled, for example albacore holes, or stretches of reef or lagoon, for as long as they wished. This probably applied to everyone, but in some cases only outsiders. Although the coercive power of the owner may have been enough to ensure compliance, supernatural forces may have also been invoked. The second form of restriction (*rahui*) was more general and related to whole districts, on certain occasions or at particular times of the year. General restrictions on all kinds of subsistence activity, including fishing, were often enforced during mourning ceremonies for people of high status. Prohibitions were also placed on tuna fishing, at the beginning of the open sea season, until certain ceremonies had been performed, as described above.

Dye (1990) has argued that the exercising of this kind of control in the Marquesas contributed to the decline in the economic contribution of fishing, particularly offshore fishing, in the protohistoric period. Canoes and rights of access to offshore waters were held by a small number of people, to the exclusion of the majority of the population.

Figure 31: The "village divider" laying out shares from the skipjack catch (from Huntsman and Hooper 1996: 76).

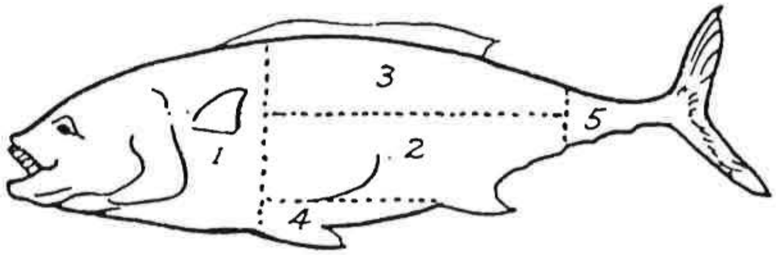


Figure 32: Ceremonial division of tuna in Samoa (from Buck 1930: 124).

1: *ulu* (head) to the high chief

2: *io alo* (sides) to the talking chief

3: *io tua* (back) tothe other chiefs

4: *ma`alo* (belly) to be put aside

5: *si`usi`u* (tail) to be discarded.

The seasonal aspect of tuna fishing in some parts of the Pacific may also be marked by ritualised behaviour, and differential access. The importance of religious sanction and hierarchical access to the fishing grounds is demonstrated in Moerenhout's account at the beginning of this chapter. Several researchers have argued that seasonal restrictions on the taking of particular species are a form of conservation measure practiced by Pacific Islanders. Titcomb (1977: 12-14) describes tabus operating in Hawaii to limit over-fishing of particular areas, and also at specific times such as spawning. Two members of the tuna family were protected in this way, the *aku* and *`opelu*. Political power and relationships with the gods are given as the most powerful determinants of action. Johannes (1981: 63-67) identifies tenure of marine fishing grounds, and restrictions on taking certain fish at certain times as functions of a traditional conservation ethic in Palau. However, the notion of conservation implies an awareness of scarcity, or that a resource is threatened. It is unclear whether this, or more political issues motivated restrictions observed in early accounts.

Summary

The aim of this chapter was to identify possible social correlates of tuna and tuna fishing in the Pacific. Contemporary and historical ethnographic accounts were considered as possible sources of information. It is clear that given the special place that offshore fishing is accorded in many Pacific island societies the capture of these fish has important social significance. By its nature offshore fishing is differentiated from other subsistence activities; it is firstly associated with an area of greater danger, that beyond the reef, and secondly, uses equipment which requires great skill. Tuna and offshore fishing can involve complex ritual behaviour to offset the uncertainty and risk involved in this activity. Offshore fish and fishing activities can have an important place in the identity and maintenance of social structure, while control over offshore fishing activities can act as a marker of religious and/or political power. The presence of fish such as tuna in archaeological sites thus may be more likely to represent the intersection of both social and economic motivations. Archaeologically these issues are difficult to investigate, but such social dimensions need to be considered if the role of fishing and fishing behaviour in archaeological communities is to be better understood.

5: Tuna in archaeological sites

The variability in the proportions of tuna remains from archaeological sites has been documented in Chapter 2. Several sites including Hane and Te Anapua in the Marquesas, Fa`ahia in the Society Islands, Motupore in Papua New Guinea, Anai`o in the Southern Cooks, and sites on Fais, in Micronesia, are notable for the relatively high proportions of tuna they contain compared to other Pacific sites (Figure 11).

This chapter discusses the archaeological fishbone collections from four of these sites, Hane, Te Anapua, Fa`ahia and Motupore; introducing the collections in terms of site location and environment, providing a brief history of the archaeological research undertaken therein, and documenting the fish remains excavated. The collections were examined with two main objectives in mind:

(1) to determine the number and composition of the tuna bone component of the collections to provide information on the nature of tuna remains in sites, and

(2) to examine reconstructions of the fish catches, and establish the relative abundance of tuna, in order to address questions about the nature of fishing undertaken by the occupants of the sites, and the approach to tuna fishing.

Where appropriate fish bone from each collection was divided into chronological periods based on stratigraphic levels and radiocarbon dates to enable a consideration of any variations through time. Any observed spatial or areal divisions in the site were also considered.

To enable the reconstruction of fish catches considered in this study it is necessary to use a value such as MNI which provides an estimate of the relative abundances of fish represented by bones in a site. The method of analysis used is one developed in New Zealand for the treatment of archaeological fishbone collections. This method has been progressively refined and used in the analysis of large numbers of archaeological collections from the Pacific region held in the Museum of New Zealand database (see Leach 1986). The basic unit of analysis is the assemblage, which is defined as the material recovered from a single excavation unit. Thus all the bone from one excavation square and one excavation layer is designated as an assemblage. The Minimum Number of Individuals is calculated with reference to these assemblage units. The MNI calculated from these assemblages are aggregated to arrive at MNI for various areal or chronological divisions within the site or for the entire site. This process of aggregation does not therefore affect relative abundance, which is the object of the analysis (Davidson, Fraser *et al.* n.d.: 6). The calculation of minimum numbers follows the general technique of Chaplin (1971). No attempt is made to increase MNI by taking into account any observed size mis-matches. Tables of NISP for the sites are provided in Appendix 2.

In order to investigate the nature of tuna fishing in the sites it is useful to contextualise this activity in terms of the overall approach to fishing adopted by people. Fishing strategies all incorporate an element of selectivity, in that each technique is aimed at a particular fish or group of fish. Some may be highly selective, and take only one or two kinds of fish, while others may catch many different kinds of fish at one time. The approach adopted by people towards offshore taxa may be indicated by the composition of the fish catch. Certain behaviours of tuna, such as their habit of feeding at the surface in schools, have resulted in the development of specific strategies using lures that take advantage of large aggregations of biting fish. Fish with similar habits may also be caught in this way. Other methods such as hook and line fishing are more generalised and may catch a greater range of acceptable fish. Baited hooks may be used to catch a range of demersal fishes, including groupers, rock cods, snapper and emperors. Alternatively, catches may the result of opportunity as opposed to specific intent. Opportunities to catch desirable fish outside of planned fishing activities are likely to be seized. For example, lures are carried whenever canoes venture beyond the reef on Tokelau, regardless of the planned fishing activity, against the chance that a school of pelagic fish will be sighted (Gillet 1985).

Both ethnohistoric records and contemporary data on tuna in the Pacific describe a distribution which is subject to fluctuations in abundance. In addition, weather patterns also affect the availability of this resource in terms of access to fishing grounds, as can cultural prohibitions. It is possible therefore that the tuna bones recovered from archaeological sites in the Pacific are the result of fishing activity undertaken during specific times of the year. This is likely to have been the case for several collections in the database, although this has not been investigated archaeologically.

The role of seasonality in prehistoric subsistence is not usually a focus of investigations of tropical Pacific economies, being of more concern in temperate areas with marked seasonal variations. Such variations may result in shifting settlement patterns, subject to resource availability. It is therefore necessary to have some understanding of the type of the sites from which tuna bones are being recovered. In the case of village sites with long chronologies, probably occupied all year round, the contribution of tuna can be seen as one component of the economy. While tuna may or may not have been the focus of the fishing effort for one part of the year, in overall terms the contribution to the economy is reflected in the relative abundances for the site.

The interpretation of fish remains from sites which may have had a specific function and been occupied intermittently is more problematic. This is particularly the case for sites such as 'fishing camps', sites which may have been occupied for a variety of reasons, possibly motivated by particularly good fishing conditions or social purposes. Faunal remains from such sites are likely to represent a specific event in space and time, and can not be seen as representative of fish in the overall economy. Several sites in the database are likely to have functioned in this way, including Te Anapua, which is a cave site in a remote locality.

Selected sites

Hane

Background

Hane is located on Ua Huka in the southern Marquesas Islands of East Polynesia. The site was discovered in 1963 by Sinoto and Kellum. In 1964 they excavated two discrete areas (A and B) and dug a number of test pits. The excavation revealed extensive structural evidence, including stone pavements, postholes and oven features, and recovered human burials and a wide range of artefacts and faunal remains from stratified contexts (Sinoto 1966, Sinoto and Kellum 1965). Sinoto carried out further excavations in 1965 (Sinoto 1966). The fish bone collection consists of bones retained in sieves during the excavation of some squares. The majority of the material is from clusters of adjacent squares near the centres of A and B respectively (Figure 33).

The central part of Area B provided the reference stratigraphy of six levels for the site. Sinoto was able to relate other areas of the site to this sequence, and added a seventh level not represented at the centre of B (Sinoto and Kellum 1965: 16). These levels were then assigned to the cultural sequence of four phases proposed by Sinoto for Marquesan prehistory, shown in

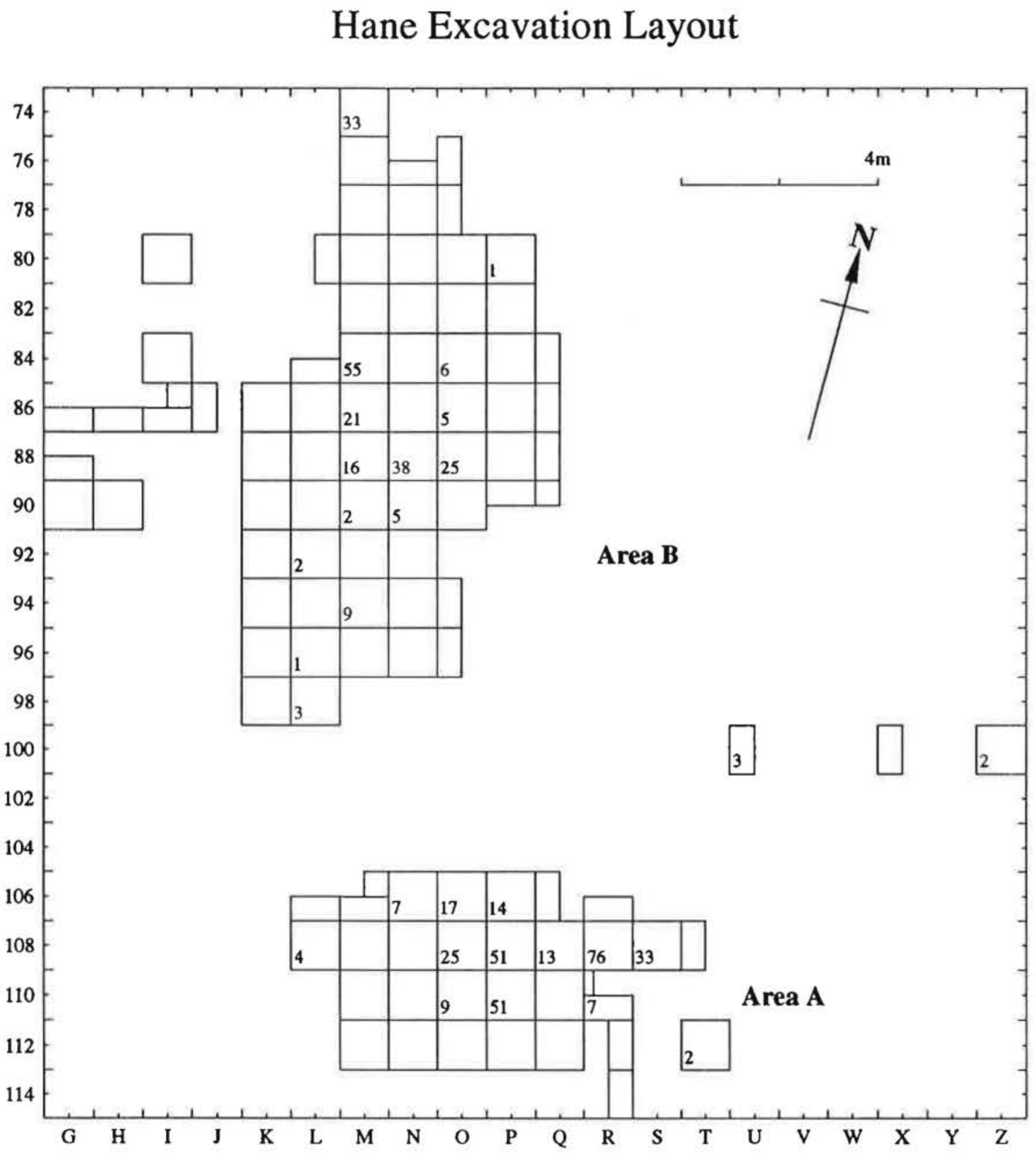


Figure 33: Plan of the Hane site, showing the distribution of identified tuna bones.

Figure 34. According to Sinoto's interpretation the occupation of Hane spans three of these phases.

The two series of radiocarbon dates obtained for the site, however, do not present a clear picture of the chronology. Based on re-interpretation of the published data several alternative explanations of the site's prehistory have been proposed. Kirch (1986: 27) has argued for a longer duration for the occupation of Hane, possibly beginning in the second half of the first millennium BC, which involved a series of cultural changes. Anderson *et al.* (1994) reject Kirch's interpretation, arguing that the lower levels of the site represent a single relatively brief occupational phase, beginning probably around the middle of the first millennium A.D. Rolett's (1989: 86-93) review of the radiocarbon dates for the site supports Sinoto's conclusion that the earliest part of the site is not represented in Area A, while the age of the earliest deposits in Area B, and hence the site as a whole, can not be precisely determined. The chronology at Hane has been the subject of a number of evaluations and re-evaluations other than Kirch, Anderson and Rolett's; and a completely satisfactory understanding of this complex site may not be possible.

Hane is situated at the mouth of a river valley, at the head of a relatively long and narrow bay (Figure 35). While the beach is sandy and suitable for canoe launching, the outer shores of the bay form a rocky coastline. A small island, Motu Hane, is positioned between Hane and the next bay, and is separated from the mainland by a narrow channel (Figure 36). Broad underwater terraces surround some islands in the Marquesas group, including Ua Huka, at a depth of 60-75m below sea level (Rousse cited in Davidson, Fraser *et al.* n.d.: 3). Although there is no coral reef, coral colonies are present everywhere in varying quantities. The inshore environment of the Marquesas has been described as a tropical reef, rather than a coral reef (Davidson, Fraser *et al.* n.d.: 4). The reef fishes found in this environment are very similar to other parts of East Polynesia, although there are fewer species of some families including Chaetodontidae and Balistidae (Davidson, Fraser *et al.* n.d.: 4).

Early/Late	**Phase**	**Level**: Area B	**Level:** Area A
Late	IV	I-III	
	III	IV	
Early	II	V-VIa	I-III
	I	VI-VII	IV-VI

Figure 34: Proposed chronology of the Hane site (Sinoto and Kellum 1965: 40, Sinoto 1970: 131).

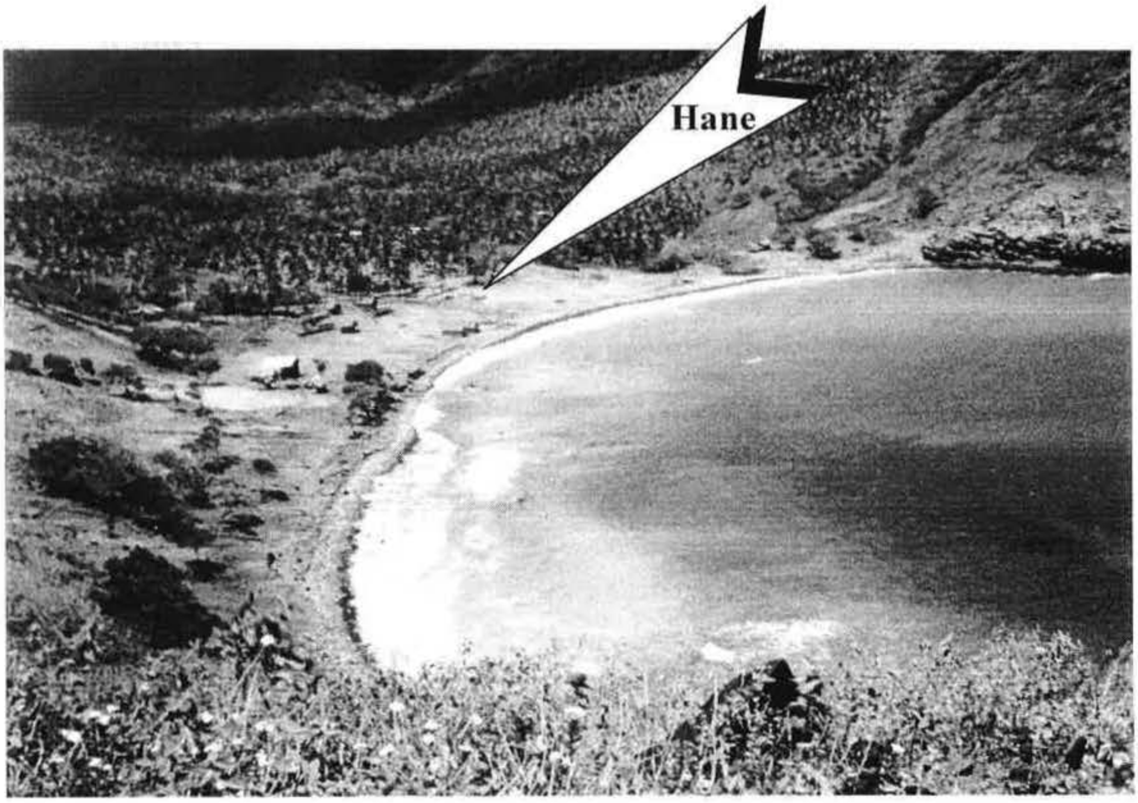


Figure 35: The location of the Hane site (Davidson *et al.* n.d.)

Figure 36: View of Motu Hane, from the Hane site (Davidson et al. n.d.)

Results:

The MNI of fish families identified from Hane are listed in Table 2, in decreasing order of abundance. Fish from assemblages which could not be confidently assigned to Sinoto's chronology for the site were also included in the total. Scombridae dominate the catch, making up 25%. Other substantial contributors include Serranidae and Carangidae. Further contributions are made by Elsamobranchs, Lutjanidae and Lethrinidae. Teleostomi represent identifiable bones which could not confidently be identified from the comparative collection. Several species are encompassed by this total, which on their own would not have a made a major contribution. Tentative identifications include Kuhliidae and Cirrhitidae.

The high numbers of tuna contrast with previous analyses of the fish remains from Hane (Kirch 1973, Dye 1990). This is very likely to be the result of the use of the caudal complex of bones in the identification of this family. Table 3 lists the number of identified elements of Scombridae from Hane. The majority of identifications were of these special bones as opposed to parts of the cranial anatomy. It is possible that differential survival rates may account for the higher proportion of caudal bones in the site. However, there is virtually no information on differential survival of fish remains in the Pacific, though a number of suggestions have been made. The oily bones of Ruvettus may not survive well (Severance 1986: 38), nor the fragile bones of flying fish (Kirch and Yen 1982: 292). On the other hand, the pharyngeal bones of some fishes, such as parrotfish and porcupine fish, are considered more durable than other kinds of bones (Butler 1988: 109). Until fundamental research in this field is carried out, it is unwise to proffer 'differential survival' as a possible reason for unusual imbalances in abundance of different species or anatomy. Only one tuna was identified to species level, this was a dogtooth tuna (*Gymnosarda unicolor*), identified on the basis of its distinctive dentition.

In order to assess any temporal or spatial variation the assemblages were assigned to one of four Phases, and also grouped by Area (Table 4). Although it appears that several trends are demonstrated by the data, in many cases the samples are too small and the error margins too large for these to be significant (Davidson, Fraser *et al.* n.d.: 6). Two trends which are significant are the high proportion of tuna in Area A , Phase II, and the high proportion of Serranidae and the relatively large number of families overall in Area B Phase IV.

Table 2: The relative abundance of fish families at Hane all assemblages combined (from Davidson, Fraser *et al.* n.d.).

Family Name	*MNI*	*Percent*		
Scombridae	137	25.70	±	3.8
Serranidae	84	15.76	±	3.2
Carangidae	67	12.57	±	2.9
Teleostomi	39	7.32	±	2.3
Lutjanidae	38	7.13	±	2.3
Elasmobranchii	36	6.75	±	2.2
Lethrinidae	26	4.88	±	1.9
Scaridae	16	3.00	±	1.5
Coridae/Labridae	15	2.81	±	1.5
Holocentridae	14	2.63	±	1.5
Diodontidae	11	2.06	±	1.3
Acanthuridae	7	1.31	±	1.1
Belonidae	7	1.31	±	1.1
Kyphosidae	7	1.31	±	1.1
Balistidae	5	0.94	±	0.9
Mullidae	4	0.75	±	0.8
Sphyraenidae	4	0.75	±	0.8
Myliobatiformes	4	0.75	±	0.8
Aphareidae	3	0.56	±	0.7
Ostraciidae	3	0.56	±	0.7
Nemipteridae	2	0.38	±	0.6
Anguillidae	1	0.19	±	0.5
Aulostomidae	1	0.19	±	0.5
Muraenidae	1	0.19	±	0.5
Leptocephalidae	1	0.19	±	0.5
Total	533	100		

Table 3: Number of identified elements of tuna from Hane.

Anatomy	*NIE*
Left Dentary	10
Right Dentary	10
Left Articular	2
Left Premaxilla	6
Right Premaxilla	1
Ultimate Vertebra	103
Vertebra	404
Total	536

Table 4: Relative abundance of fish families at Hane according to Area and Phase (from Leach *et al.* 1997: 55).
Columns 1-4: Area A phases 1-4 (MNIs = 87, 110, 4, 5)
Columns 5-8: Area B Phases 1-4 (MNIs = 109, 45, 6, 70)

Family %	**1**		**2**		**3**		**4**		**5**		**6**		**7**		**8**	
Scombridae	26.4 ±	10.0	32.7 ±	9.3	50.0 ±	76.8	40.0 ±	63.6	24.8 ±	8.6	17.8 ±	12.6	16.7 ±	44.3	12.9 ±	8.7
Epinephelidae	9.2 ±	6.7	14.5 ±	7.1	- -	-	- -	-	18.3 ±	7.8	15.6 ±	12.0	16.7 ±	44.3	22.9 ±	10.7
Carangidae	17.2 ±	8.6	11.8 ±	6.5	- -	-	20.0 ±	53.8	11.9 ±	6.6	17.8 ±	12.6	16.7 ±	44.3	7.1 ±	6.8
Teleostomi	16.1 ±	8.4	7.3 ±	5.4	25.0 ±	68.2	- -	-	4.6 ±	4.4	6.7 ±	8.6	- -	-	5.7 ±	6.2
Elasmobranchii	6.9 ±	6.0	10.9 ±	6.3	- -	-	- -	-	8.3 ±	5.7	2.2 ±	5.5	- -	-	7.1 ±	6.8
Lutjanidae	6.9 ±	6.0	7.3 ±	5.4	- -	-	- -	-	5.5 ±	4.8	11.1 ±	10.5	- -	-	5.7 ±	6.2
Lethrinidae	4.6 ±	5.0	4.5 ±	4.4	- -	-	20.0 ±	53.8	5.5 ±	4.8	6.7 ±	8.6	- -	-	5.7 ±	6.2
Coridae/Labridae	2.3 ±	3.8	0.9 ±	2.2	- -	-	- -	-	7.3 ±	5.4	2.2 ±	5.5	16.7 ±	44.3	1.4 ±	3.5
Scaridae	1.1 ±	2.8	2.7 ±	3.5	- -	-	20.0 ±	53.8	1.8 ±	3.0	4.4 ±	7.3	- -	-	4.3 ±	5.5
Holocentridae	1.1 ±	2.8	- -	-	25.0 ±	68.2	- -	-	2.8 ±	3.6	4.4 ±	7.3	- -	-	4.3 ±	5.5
Diodontidae	- -	-	- -	-	- -	-	- -	-	0.9 ±	2.3	2.2 ±	5.5	16.7 ±	44.3	7.1 ±	6.8
Belonidae	1.1 ±	2.8	- -	-	- -	-	- -	-	4.6 ±	4.4	- -	-	- -	-	1.4 ±	3.5
Kyphosidae	4.6 ±	5.0	- -	-	- -	-	- -	-	0.9 ±	2.3	2.2 ±	5.5	- -	-	- -	-
Acanthuridae	1.1 ±	2.8	- -	-	- -	-	- -	-	- -	-	2.2 ±	5.5	- -	-	4.3 ±	5.5
Myliobatiformes	- -	-	3.6 ±	4.0	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-
Aphareidae	1.1 ±	2.8	1.8 ±	3.0	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-
Balistidae	- -	-	0.9 ±	2.2	- -	-	- -	-	- -	-	2.2 ±	5.5	- -	-	1.4 ±	3.5
Ostraciidae	- -	-	- -	-	- -	-	- -	-	- -	-	2.2 ±	5.5	- -	-	2.9 ±	4.7
Sphyraenidae	- -	-	0.9 ±	2.2	- -	-	- -	-	1.8 ±	3.0	- -	-	- -	-	- -	-
Mullidae	- -	-	- -	-	- -	-	- -	-	0.9 ±	2.3	- -	-	- -	-	1.4 ±	3.5
Anguillidae	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	1.4 ±	3.5
Aulostomidae	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	1.4 ±	3.5
Nemipteridae	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	1.4 ±	3.5
Muraenidae	- -	-	- -	-	- -	-	- -	-	- -	-	- -	-	16.7 ±	44.3	- -	-
Totals	**100.0**		**100.0**		**100.0**		**100.0**		**100.0**		**100.0**		**100.0**		**100.0**	

Fishing at Hane:

Several inferences can be drawn from the reconstruction of the fish catch at Hane about the approach to prehistoric fishing in the site. It is clear that pelagic fish made a significant contribution to the catch. Belonidae, Sphyraenidae and Carangidae are also present. Members of the Carangidae family are free ranging fish, and include both offshore species and others which are more closely associated with reefs and lagoon waters. There is, however, evidence for a slight decline in the importance of this group of fish. Also important were fish usually associated with the reef edge. Within in this group, the Serranidae family also contains a wide range of species with a diverse range of habitats. It is possible some of these fish represented in the collection were taken from deeper waters offshore. There is also an increase in the importance of this family through time. The offshore shelves around several islands provide well known fishing grounds in the Marquesas today (Rolett 1989: 208). Most of the remaining fish families are from shallow inshore waters. Many do not appear until later in the chronology of the site, and are present in only very small numbers. Notably there are also relatively few members of the Scaridae family in the catch. Elsewhere in the Pacific these fish form important components of the diet (Fleming 1986).

It appears that the majority of the fishing effort at Hane was concentrated towards pelagic fish, and those found around reef edges and drop-offs. Inshore species did not receive a great detail of attention, although this did increase over time. The presence of a number of pelagic predators in the site suggests the use of surface targeted strategies, probably using trolling lures. These fish contributed up to 40% of the catch. The high percentage of tuna suggests a particular strategy which targeted these fish. A further 30% were probably also caught using hook and line techniques; these are members of the Serranidae, Lutjanidae, Lethrinidae, Mullidae, Labridae, Nemipteridae, and possibly Holocentridae and Balistidae families (Rolett 1989: 211-12, 228). These fish families are associated with reef edges, are also carnivorous, and were probably caught by angling with a demersal baited hook. Sub-surface tuna may also have been taken with this method. Rolett (1989: 224) observes that dogtooth tuna are caught by deep baited line fishing in the Marquesas today. Other fishing methods such as netting, trapping and general foraging do not feature strongly in the site.

The paucity of inshore fish could be seen as consistent with the restricted nature of the inshore environment which lacks extensive reef flats and lagoon waters. Walter (1991) has suggested that in the Cook Islands this factor resulted in the specialisation of fishing strategies targeting the more productive reef edge zone. For the people of Hane this may have resulted in a similar emphasis in line fishing techniques, probably both from the rocky shore and canoes, with an additional focus on the resource provided by the pelagic fishery, particularly tuna.

Te Anapua

Background

Te Anapua is a rock shelter at the southern end of Ua Pou island, in the Marquesas. The site was excavated from the early 1980s under the direction of Ottino. The excavations consisted of an areal excavation of the interior of the shelter, which exposed the uppermost layers only, and a deep sondage (test pit) at the junction of the flat interior and the beginning of the talus slope (Leach *et al.* 1997b: 50). The material from the sondage was sieved through 2 mm mesh, and the material retained was sent to the Museum of New Zealand Archaeological Laboratory for analysis.

Fifteen stratigraphic levels were determined, and grouped by Ottino into five major levels according to sediments (Table 5). No fish remains were recovered from the sterile deposits of Level I, so the analysis is confined to Level II to IV. A radiocarbon date of 2100±95BP on charcoal was obtained from deep in the site. A shell sample from the same level has been dated to 770±50BP. Ottino regards the earlier date as more acceptable (Leach *et al.* 1997b: 52).

Te Anapua is located in a small bay, surrounded by high cliffs, and is difficult to access except by sea. It is known to present day Marquesans as a "fishermen's cave" (Leach *et al.* 1997b: 51).

Table 5: Levels, layers and spits at Anapua Rock Shelter (from Leach *et al.* 1997b: 52).

Description	Level	Layers	Spits
Ashy, charcoal-stained deposits with clearly defined hearths and earth ovens. European material present	V	15b, 15a	1 to 6
Fine, ashy deposits, little of no evidence of living surfaces or structures	IV	14b, 14a, 13	8 to 17
Largely sterile layer of scree and colluvium	III	12	19
A deep deposit of ashy, charcoal-stained layers alternating with colluvium	II	11 to 3	21 to 36
Sterile deposit resting on the rock floor of the shelter	I	2 to 1	37 to 39

Note: Spits 7, 18 and 20 are excluded because they included material from more than one level.

Results

A total of 26 fish families were identified at Te Anapua (Leach *et al.* 1997b). Table 6 shows their relative abundance. This confirms that the dominant catch in the site are members of the Scombridae family, contributing nearly 25%. Following tuna in abundance are four groups of fish occurring in similar frequencies; these are the Serranidae, Holocentridae, Balistidae and Lutjanidae families. Of the 26 fish families identified at the site, these five with the addition of the next highest ranked family (Labridae), make up over 70% of the total catch. The remaining 20 families, which includes Teleostomi (unidentified), are mainly inshore species which are present in very low numbers.

The tuna bone identified from Te Anapua is listed in Table 7, with the majority of identifications made of bones from the caudal complex. Identifications of cranial elements in the site are variable.

Measurements of the "caudal peduncle" or hypural plate, were made by Leach *et al.* (1997b: 56-57). Their analysis of these measurements showed significantly positive skewness and kurtosis, and this non-normality is shown in their histogram in Figure 37. This is suggested by Leach *et al.* to be the result of more than one species contributing to the catch. Several possible species are considered for the smaller individuals: skipjack (*Katsuwonus pelamis*), bonito (*Sarda sp.*) and mackerel (*Rastrelliger sp.*). An examination of the hypural plates undertaken during the course of this research shows that the species present are members of one or both of the two higher tribes in the Scombridae family, Thunnini and Sardini, as the notch on the posterior edge of the bone, which is characteristic of the lower tribes, is not present. The non-normality in the collection could be due to different species from these tribes being present, or alternatively fish from different size/age grades of the same species may have been caught. Variation is also present in the shape of the centrum of the penultimate vertebra of tuna from the site. Oval shaped centra were present in a range of sizes, while round centra were observed on many of the larger bones. This also suggests at least two different species are present in the collection.

The assemblages were grouped by the stratigraphic levels identified by Ottino, in order to consider any temporal variation (Table 8). Several trends are evident in the results. There is a

Table 6: The relative abundance of fish families at Te Anapua (after Leach *et al.* 1997b: 54).

Family	*MNI*	*%*	*Error*
Scombridae	109	24.77 +-	4.15
Serranidae	56	12.73 +-	3.23
Holocentridae	53	12.05 +-	3.16
Balistidae	39	8.86 +-	2.77
Lutjanidae	36	8.18 +-	2.67
Lethrinidae	24	5.45 +-	2.24
Scaridae	20	4.55 +-	2.06
Carangidae	16	3.64 +-	1.86
Elasmobranchii	16	3.64 +-	1.86
Belonidae	10	2.27 +-	1.51
Acanthuridae	10	2.27 +-	1.51
Ostraciidae	10	2.27 +-	1.51
Coridae/Labridae	7	1.59 +-	1.28
Mullidae	6	1.36 +-	1.20
Diodontidae	6	1.36 +-	1.20
Lamniformes	5	1.14 +-	1.10
Aulostomidae	3	0.68 +-	0.88
Scorpaenidae	3	0.68 +-	0.88
Kyphosidae	2	0.45 +-	0.74
Aluteridae	2	0.45 +-	0.74
Teleostomi	2	0.45 +-	0.74
Muraenidae	1	0.23 +-	0.56
Caesiodidae	1	0.23 +-	0.56
Nemipteridae	1	0.23 +-	0.56
Platacidae	1	0.23 +-	0.56
Tetrodontidae	1	0.23 +-	0.56
Total	**440**	**100**	

Table 7: Number of identified elements of tuna from Te Anapua.

Anatomy	*NIE*
Left Dentary	21
Right Dentary	17
Left Articular	15
Right Articular	12
Left Premaxilla	6
Left Quadrate	30
Right Quadrate	33
Right Premaxilla	5
Left Maxilla	7
Right Maxilla	9
Ultimate Vertebra	106
Vertebra	455
Total	710

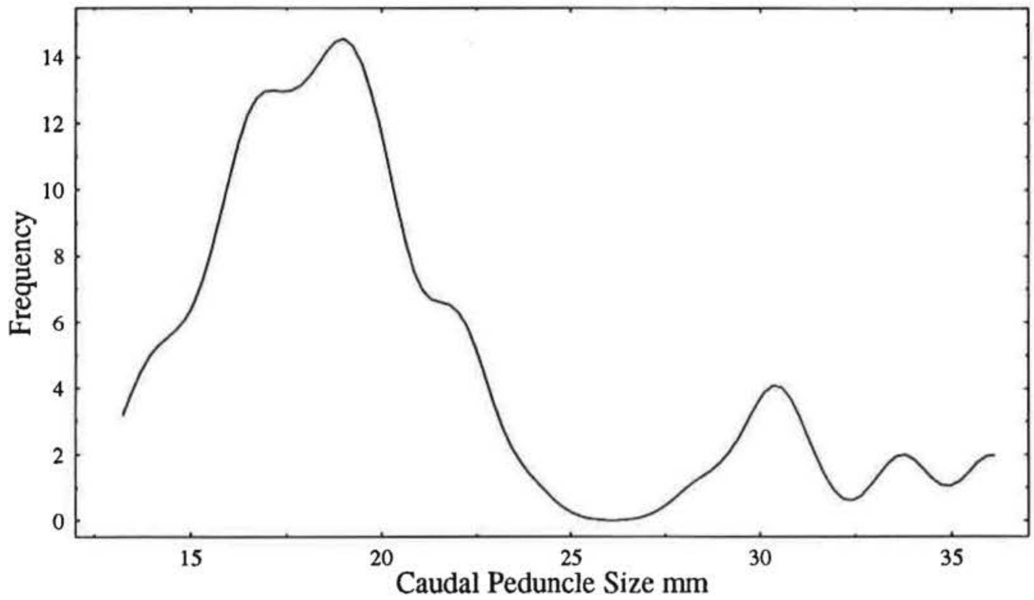


Figure 37: Size-frequency of tuna ultimate vertebra measurements at Te Anapua (from Leach *et al.* 1997b: 60).

Table 8: Fish Percentages by Family for Four Main Stratigraphic Levels, Te Anapua (from Leach et al. 1997b).

Family	II	III	IV	V
Scombridae	33.67 ± 6.82	16.67 ± 44.32	17.84 ± 5.38	13.64 ± 17.41
Serranidae	11.56 ± 4.69	16.67 ± 44.32	12.68 ± 4.70	22.73 ± 20.76
Holocentridae	7.04 ± 3.80	16.67 ± 44.32	16.43 ± 5.21	13.64 ± 17.41
Balistidae	10.55 ± 4.52	0.00 ± 8.33	7.04 ± 3.67	13.64 ± 17.41
Lutjanidae	10.55 ± 4.52	0.00 ± 8.33	6.10 ± 3.45	9.09 ± 14.95
Lethrinidae	4.52 ± 3.14	16.67 ± 44.32	6.10 ± 3.45	4.55 ± 11.46
Scaridae	3.02 ± 2.63	0.00 ± 8.33	6.10 ± 3.45	4.551 ± 11.46
Carangidae	3.02 ± 2.63	0.00 ± 8.33	4.23 ± 2.94	4.55 11.46
Elasmobranchii	3.02 ± 2.63	0.00 ± 8.33	4.23 ± 2.94	4.55 ± 11.46
Belonidae	0.50 ± 1.23	0.00 ± 8.33	3.76 ± 2.79	4.55 ± 11.46
Acanthuridae	1.01 ± 1.64	33.33 ± 53.85	2.82 ± 2.46	0.00 ± 2.27
Ostraciidae	2.01 ± 2.20	0.00 ± 8.33	2.35 ± 2.27	4.55 ± 11.46
Coridae/Labridae	2.01 ± 2.20	0.00 ± 8.33	1.41 ± 1.82	0.00 ± 2.27
Mullidae	2.51 ± 2.43	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Diodontidae	1.01 ± 1.64	0.00 ± 8.33	1.88 ± 2.06	0.00 ± 2.27
Lamniformes	0.50 ± 1.23	0.00 ± 8.33	1.88 ± 2.06	0.00 ± 2.27
Aulostomidae	1.01 ± 1.64	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Scorpaenidae	1.01 ± 1.64	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Kyphosidae	0.50 ± 1.23	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Aluteridae	0.50 ± 1.23	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Teleostomi	0.50 ± 1.23	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Muraenidae	0.00 ± 0.25	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Caesiodidae	0.00 ± 0.25	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Nemipteridae	0.00 ± 0.25	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Platacidae	0.00 ± 0.25	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Tetrodontidae	0.00 ± 0.25	0.00 ± 8.33	0.47 ± 1.15	0.00 ± 2.27
Totals	**100.0**	**100.0**	**100.0**	**100.0**

consistent decline in the relative abundance of tuna in the catch, from 34% in Level II to 14% in Level IV. This is paralleled by an increase in Serranidae from 12% to 23%, and Holocentridae from 7% to 13%. Leach *et al.* (1997b: 54) point out that an examination of the confidence range associated with this percentage statistic shows that the changes can only be confirmed in Levels II and IV.

Fishing at Te Anapua

The pattern of fishing at Te Anapua appears very similar to that practised at Hane. The reconstruction of the catch suggests an approach which is directed primarily to fish from pelagic and reef edge and benthic waters. The importance of pelagic fish, particularly tuna, declines through time, with a commensurate rise in reef edge species. A range of inshore species were also taken in low numbers; as a group the frequency and variety caught are highest later in the chronology of the site.

Again, an emphasis on line fishing is inferred, with fishing for tuna and other pelagic fish being done with lures, and baited hooks used for the demersal species such as groupers, emperors and wrasses. Balistidae are small mouthed fish which are taken by nets elsewhere in the Pacific. They are however carnivorous, and will take a small baited hook. Rolett (1989: 228) has documented a contemporary method for catching these fish with a hook in the Marquesas, which may have some antiquity. The presence of relatively high numbers of Holocentridae in the site alludes to the possibility of fishing occurring at night. These are small fishes which are nocturnal in habit, retreating into crevices and holes in shallow water during the day (Munro 1967: 139). In his study of Marquesan fishing practices Rolett (1989: 211-212) identified three specialised nocturnal fishing methods using a hook and line for these fish, which may have also been used by the people of Anapua in prehistory.

The similarities between Hane and Te Anapua (see Figure 38) are interesting in that the sites are believed to span similar time periods, but to have had different functions. Based on structural evidence, Hane is believed to have been a residential site during much of its occupation, while Te Anapua is known as a fishing cave, and has been occupied intermittently. It appears that fishers in both sites adopted a similar approach to fishing. The people at Te Anapua exploited the range of possible fish available to them from the marine environment, as opposed to focusing on certain fish to the exclusion of everyday fishing activities. The presence

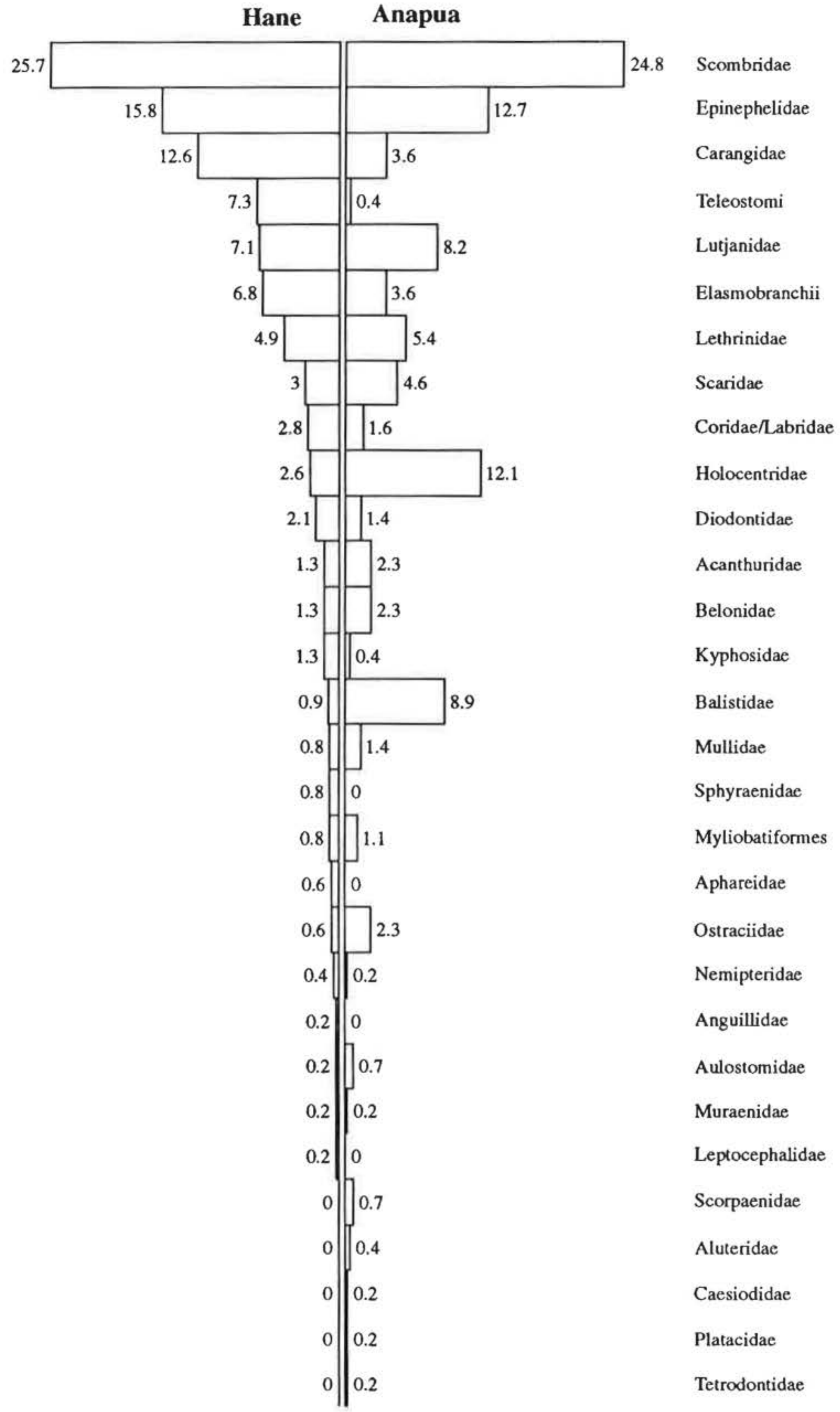


Figure 38: The relative abundance of fish families at Hane and Te Anapua (from Davidson, Fraser *et al.* n.d.)

of Holocentridae and Balistidae could be an exception to this, representing concentration on particular kinds of fish, and fishing strategies.

The pattern of fishing inferred from the results of the fish bone analysis from both Hane and Te Anapua is also evident at another Marquesan site, Hanamiai, on the island of Tahuata (Rolett 1989). Although results from this site are not directly comparable with those analysed here, the dominance of tuna is also obvious. Rolett (1989: 224) identified 87 Scombridae dentaries and premaxillae from a total of 495 identified fish bones. Other fish occurring in similar proportions to those found at Hane and Te Anapua include Belonidae, Lutjanidae, Serranidae and Carangidae. Again the main fishing methods probably involved trolling for pelagic species, and the use of demersal baited hooks. Rolett (1989: 234) also identified changes in fishing practices at Hanamiai, on the basis of faunal remains and fishing gear in the site, the most significant being a decline in pelagic fishing, and also deep sea fishing, and a commensurate increase in inshore fish and fishing techniques.

The analysis of fish bone from these sites seems to indicate a shift in fishing effort, from pelagic and deep sea fish, to those found in inshore waters. Although there is a decline in the abundance of tuna in all three sites, at the end of the sequences tuna is still making a relatively high contribution to the catch, 14% at both Hane, and Te Anapua. Davidson, Fraser *et* al. (n.d.: 6) review several factors which could have affected fishing in the Marquesas through time. These include primarily cultural explanations, where a shift away from inshore to offshore resources is related to increasing social tension (cf. Dye 1990), a decline in inter-island travel and a tendency to stick closer to home. Davidson, Fraser *et al.* also raise the possibility that changing patterns of weather and currents may have affected tuna abundance, and that Marquesan fishermen of the late period devoted just as much effort to tuna fishing as their predecessors had, but with diminishing success.

Vaito`otia-Fa`ahia

Background

The Vaito`otia-Fa`ahia complex is located on the island of Huahine in the Society Islands of French Polynesia. The sites lie within the grounds of the Bali Hai hotel, and were first discovered as a result of construction work undertaken by the hotel in 1972. The Bali Hai occupies an area of land which is divided by a traditional land boundary between Fa`ahia in the north and Vaito`otia in the south. Excavations in both areas have yielded significant amounts of cultural material, including artefacts of wood, stone, shell and whale bone and large collections of faunal remains.

Archaeological investigations of the complex between 1973-1981 were carried out by the Bishop Museum, under the direction of Sinoto. Initial excavations took place at Vaito`otia, adjacent to a large pond where artefacts were first located after dredging activities (Sinoto 1974, 1975, 1976, 1977, Sinoto and McCoy 1975a, 1975b). In 1977 the focus of the excavations shifted to the Fa`ahia land division (Sinoto 1978, 1979, 1982, Sinoto and Han 1980, 1981). Five excavation sections were established in this part of the site (Figure 39). The excavations at Fa`ahia confirmed that the site was spread over the entire Fa`ahia and Vaito`otia land tracts. The designation of the two sites does not therefore represent a cultural separation, but is rather a convention based on present land divisions (Sinoto 1983: 596). Different activity areas were however able to be determined within the complex. Storage structures and a fish-hook manufacturing area were located in Vaito`otia, and an adze and canoe manufacturing area in Fa`ahia.

Two cultural horizons were identified at Vaito`otia-Fa`ahia, a lower waterlogged layer, and an upper cultural layer thought to contain recent occupational debris. The age of the earlier occupational layer, based on radiocarbon dates, has been assessed as in the range of 850 AD to 1200 AD (Leach *et al.* 1984: 183).

The excellent preservation of archaeological material recovered from the site is attributed to the waterlogged nature of the deposits. The currently swampy condition of the area is believed to be a localised phenomenon, as opposed to the result of a environmental change which would have significantly affected the associated marine environment in the past (Leach *et al.* 1984:

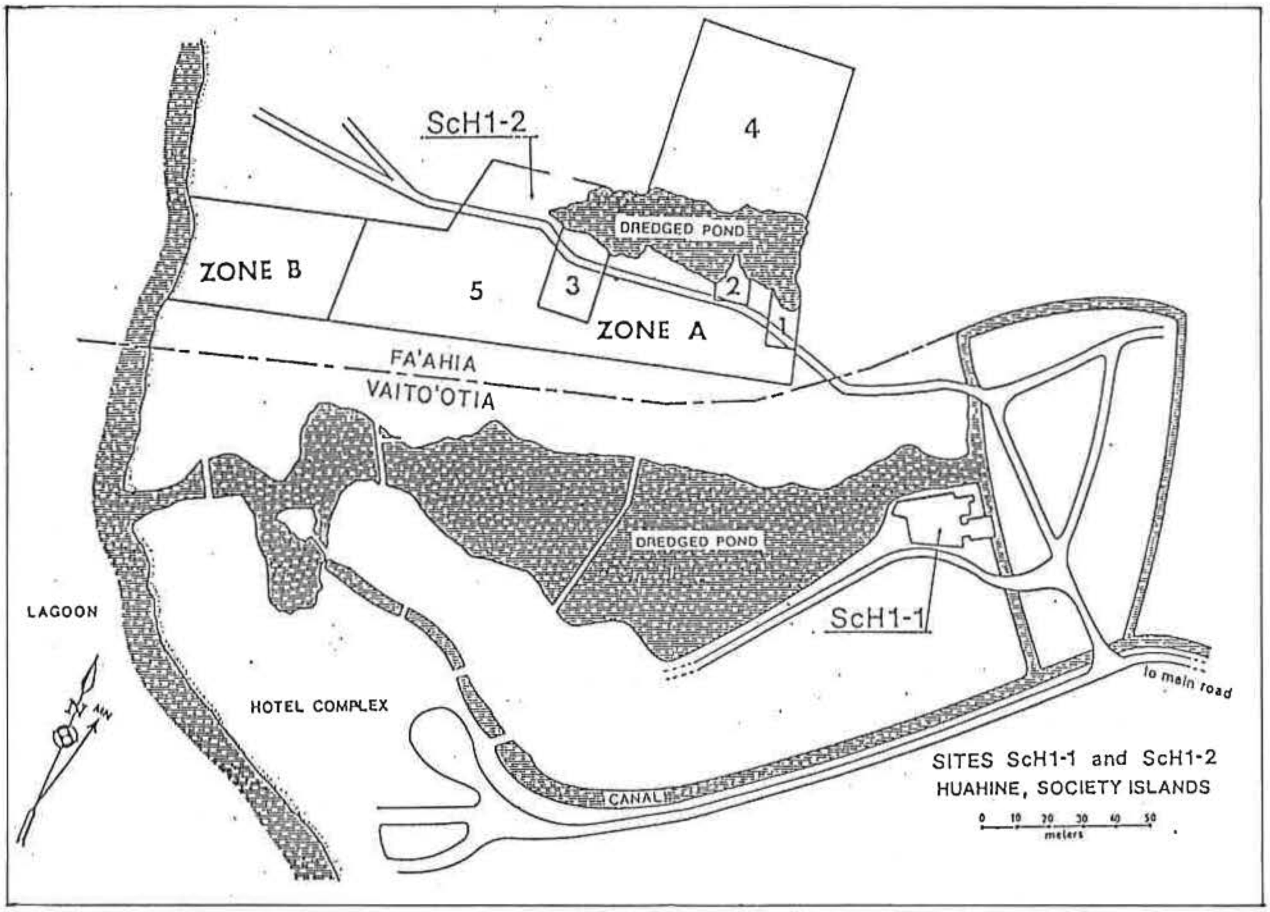


Figure 39: Plan of the Vaito`otia/Fa`ahia site, showing Bishop Museum excavations. (from Sinoto and Han 1980: 16).

185). Sinoto has interpreted this aspect of the site as the result of an isolated event such as a tidal wave which suddenly covered the site, resulting in the abandonment of associated material culture and in the drift of wooden objects to low lying areas in the site.

In 1983 further excavations commenced run by the Départemente Archéologie, under the direction of Pigeot (Figure 40). Dubois's (1986) interpretation of the geomorphology of the site differs from previous interpretations. The deposit above the earlier cultural layer is suggested to have accumulated under the calm conditions of a lagoon or lake, thus the present high water table of the area is argued to be caused by a gradual process, rather than a cataclysmic event. The site may have been abandoned to the increasing dampness of the area. In this scenario cultural material is more likely to have survived *in situ* in the site. Pigeot's excavations were therefore directed towards a greater understanding of the spatial organisation within the site, and were concentrated in Fa`ahia. As Sinoto had found the bases of posts and other domestic debris in his Section 4, excavations were carried out in this area (Figure 40). In 1983 a row of squares were excavated adjacent to Sinoto's excavations, and were expanded in an area known as Locus 1 (Pigeot 1986). Further investigations followed in the area designated Locus C50 (Pigeot 1987).

The sites at Vaito`otia-Fa`ahia are well positioned to take advantage of a wide range of marine environments (Figure 41). The complex is situated on coastal lowland in the north-west of the island, close to one of the major reef passages Avamoa. Davidson *et al.* (n.d.) describe a reef transect taken directly in front of the Bali Hai hotel. Beyond the immediate beach channel, the inner part of the lagoon consists of a reef flat with scattered dead coral and some live coral under about 2m of water. In the centre are larger reef outcrops and coral growths providing a habitat for fish such as Acanthuridae and shellfish such as *Tridacna maxima*. The outer part of the lagoon comprises a compact reef flat rising to the outer ridge. Beyond the barrier ridge the reef falls away steeply. The Vaito`otia-Fa`ahia sites would have been provided with good canoe access to open water and offshore fishing grounds via the reef passage. The exact nature of the inshore fishing environment at the time of occupation is less certain, because of the fluctuations of relative land/sea levels in the locality during the time of human occupation of Huahine (Davidson *et al.* n.d.).

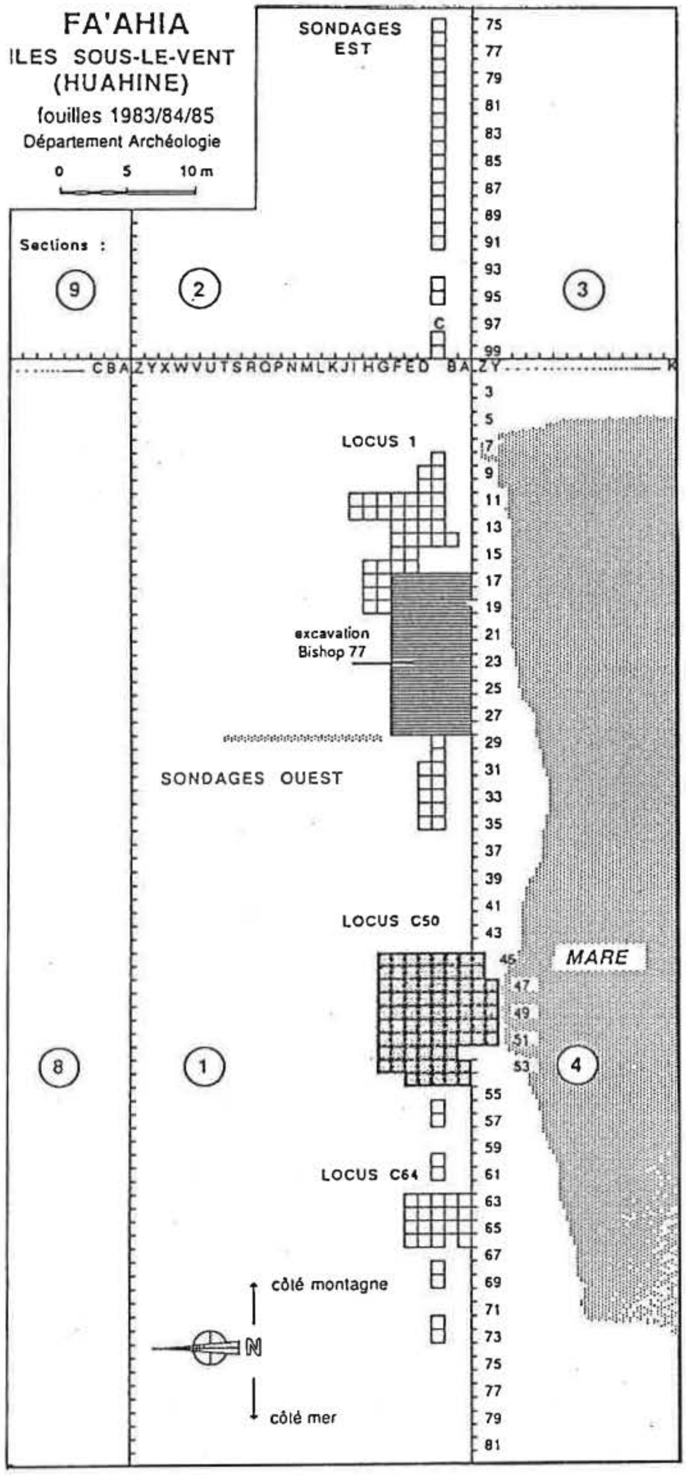


Figure 40: Plan of Fa`ahia, showing the Département Archéologie excavation area Locus C50. (from Pigeot 1987: 8).

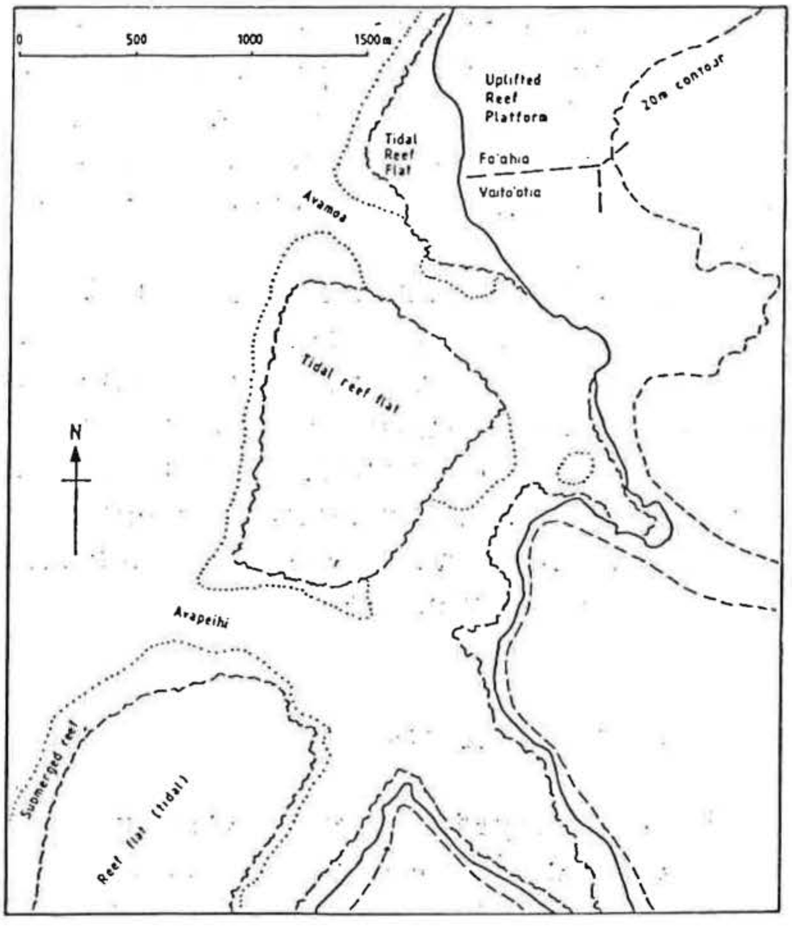


Figure 41: North-west Huahine showing the location of the Vaito`otia/Fa`ahia land divisions and the nearby terrestrial and marine environment (from Leach *et al.* 1984: 184).

Two fish bone assemblages from Vaito`otia-Fa`ahia were examined here. The first was excavated by Sinoto in the 1970s, and recovered from Section 3, Zone A, Fa`ahia. All material retained by 1/4 inch mesh in the field was kept for analysis (Leach *et al.* 1984: 183). The second assemblage was recovered during Pigeot's excavations at Fa`ahia, and comes from Locus C50, in Sinoto's Section 4. All of the material from layer b, the earlier cultural layer, and also parts of layer c and d were wet sieved.

Results:

Results from the analysis of the first collection, excavated by Sinoto, are listed in Table 9. The catch is dominated by two families of pelagic fish, Scombridae and Carangidae, which together make up 40% of the catch. Several other pelagic fish families are present, although in much smaller numbers. Fish from both families are likely to have entered the lagoon in search of prey. Parrotfish also occur in quite high numbers, contributing 14%. Three demersal families, Serranidae, Lutjanidae and Lethrinidae, rank next, and combined make up 22%.

The tuna bones identified in this collection are listed in Table 10. The structure of this collection is highly unusual. Of the 513 bones, 51 caudal vertebra and only 4 penultimate vertebra were identified, in comparison to 458 bones from the cranial anatomy. The preservation of archaeological material in the site is extremely good, attested by the large numbers of wooden artefacts recovered, and also by the identification of flying fish remains. The bones of members of this family, Exocoetidae, are very fragile and rarely recovered in archaeological contexts. It is possible that the caudal bones from tuna were not recovered, however, the material intended for faunal analysis was sieved and the remainder retained. Alternatively, tuna may have been differentially processed and transported through out the site. This possibility will be considered below.

Results from the second collection, excavated by Pigeot, are listed in Table 11. This collection is notable for the lower numbers of pelagic fish in the site, both in terms of quantity and diversity. Together tuna and Carangidae contribute 16% to the catch, much lower than in Sinoto's excavation. This collection contains 27% of parrotfish, and other inshore fish also occur in increased frequencies. Serranidae, Lethrinidae and Lutjanidae are present in similar numbers, as are other demersal families.

Table 9: The relative abundance of fish families at Fa`ahia, Sinoto's excavations.

Family	MNI	%
Scombridae	100	18.35
Carangidae	89	16.33
Scaridae	67	12.29
Serranidae	48	8.81
Lethrinidae	43	7.89
Lutjanidae	31	5.69
Balistidae	29	5.32
Diodontidae	16	2.94
Belonidae	15	2.75
Holocentridae	15	2.75
Nemipteridae	14	2.57
Coridae/Labridae	13	2.39
Elasmobranchii	11	2.02
Acanthuridae	10	1.83
Mullidae	7	1.28
Anguillidae	6	1.10
Sphyraenidae	6	1.10
Aulostomidae	5	0.92
Ostraciidae	5	0.92
Muraenidae	4	0.73
Tetrodontidae	3	0.55
Teleostomi	2	0.37
Chanidae	1	0.18
Exocoetidae	1	0.18
Hemirhamphidae	1	0.18
Megalopidae	1	0.18
Mugilidae	1	0.18
Scorpaenidae	1	0.18
Total	**545**	**100**

Table 10: Number of identified elements of tuna from Fa`ahia.

Anatomy	*Sinoto (NIE)*	*Pigeot (NIE)*
Left Dentary	65	7
Right Dentary	67	3
Left Articular	50	3
Right Articular	58	-
Left Quadrate	53	2
Right Quadrate	43	2
Left Premaxilla	37	3
Right Premaxilla	32	2
Left Maxilla	26	2
Right Maxilla	27	1
Caudal Peduncle	4	13
Vertebra	51	60
Total	**514**	**98**

Table 11: The relative abundance of fish families at Fa`ahia, Pigeot's excavations.

Family	MNI	Percent	
Scaridae	268	27.46	± 2.9
Serranidae	109	11.17	± 2.0
Carangidae	98	10.04	± 1.9
Scombridae	64	6.56	± 1.6
Lutjanidae	63	6.45	± 1.6
Nemipteridae	48	4.92	± 1.4
Lethrinidae	42	4.30	± 1.3
Ostraciidae	42	4.30	± 1.3
Balistidae	41	4.20	± 1.3
Coridae/Labridae	31	3.18	± 1.2
Elasmobranchii	31	3.18	± 1.2
Acanthuridae	26	2.66	± 1.1
Holocentridae	25	2.56	± 1.0
Mullidae	23	2.36	± 1.0
Teleostomi	19	1.95	± 0.9
Mugilidae	17	1.74	± 0.9
Muraenidae	7	0.72	± 0.6
Diodontidae	5	0.51	± 0.5
Scorpaenidae	4	0.41	± 0.5
Kyphosidae	3	0.31	± 0.4
Sphyraenidae	3	0.31	± 0.4
Myliobatiformes	3	0.31	± 0.4
Exocoetidae	2	0.20	± 0.3
Anguillidae	1	0.10	± 0.3
Myliobatidae	1	0.10	± 0.3
Total	**976**	**100**	

Table 10 also lists the tuna bones identified from Pigeot's excavation. The structure of this assemblage is unlike that from Sinoto's excavation, and is more in keeping with those from Hane and Te Anapua. Cranial elements are present, but in low numbers, with the majority of identifications made of caudal bones.

Fishing at Fa`ahia

The people of Fa`ahia have been described by Leach *et al.* (1984: 196) as "marine hunters" with a specialised approach to their environment, based on the analysis of material recovered from Sinoto's excavation. This characterisation draws upon the high number of pelagic fish, marine mammals and turtles recovered from the site. Although tuna and Carangidae dominate numerically, Belonidae and Sphyraenidae were also caught. These pelagic fishes may have been taken offshore, or within the deeper waters of the lagoon. The location of the site is well positioned to take advantage of such fish entering lagoon waters to feed. Fish from a variety of other environments accessible from the site are also present, including demersal species found along the reef edge, and inshore shallow water fishes.

The majority of fish recovered during Sinoto's excavation could have been taken on lines. In particular, the large proportion of pelagic fish suggest specific strategies were used to catch these fish. Trolling with lures is one likely method for surface schooling tuna, and sub-surface tuna may have been taken with baited hooks. Nordhoff (1930) discusses strategies using both these methods in his account of offshore fishing in the Society Islands, although the time depth of these methods is difficult to assess. Rolett (1989: 236) describes a specific strategy for catching Belonidae in the Marquesas, while Leach *et al.* (1984) also discuss two specific strategies for catching Belonidae described in ethnographic accounts from elsewhere in the Pacific. Baited hooks were likely to be used for the demersal species in the catch. By comparison, the relatively high proportions of Scaridae were probably netted or speared. They are largely herbivorous; and hence highly unlikely to be caught with hook and line. The range of other inshore and shallow waters species such as Balistidae, Diodontidae and Acanthuridae are also likely to have been caught using methods such as netting, spearing, trapping and general foraging around the reef flats.

When the fish assemblage from C50 is considered in conjunction with that from Sinoto's excavations a different approach to fishing is indicated. The numbers of inshore fish families from this area, and the commensurate lower levels of tuna and other pelagic fish, suggest resources from shallow reef waters also played a significant role in the economy of the people of Fa`ahia. Given the easy access to these resources this is perhaps not surprising, and is consistent with other patterns of resource use from similar environments in the Pacific where netting, spearing and foraging for fish in shallow reef and lagoon waters make important contributions. The proportions of tuna and Carangid together contribute 16% of the catch overall, and this suggests that pelagic fish were being deliberately caught, but did not form the main basis of protein provided by fish in the subsistence economy.

It is unusual that the relative abundance of fish families from two adjacent excavation areas should vary in composition so significantly (see Figure 42). Although recovery strategies varied, during both excavations material was collected with sieves and retained for faunal analysis, and large samples were obtained.The analysis was carried out using identical methods, so analytical bias seems unlikely as a possible cause of the variation. The chronology of the site is not perfectly clear, and it is possible that the collections come from levels that are not contemporaneous. It is possible the Sinoto collection comes from an early part of the site, while Pigeot's material is later. If this was the case the decline in offshore and line fishing demonstrated in the Marquesas may be a more widespread phenomenon. At this point in time explanations for the discrepancies between the collections are tentative at best, but it is an important question to be addressed in future.

It is also possible that Pigeot's collection spans a very limited time period. A spatial analysis was made of all structural and portable items excavated at C50 (Pigeot 1987). A number of small posts and stakes are believed to define the limits of an irregular and fairly insubstantial structure, which correlates well with the distribution of various types of objects, recovered both "inside" and "outside". These include remains of fish, turtles, coconut shells, concentrations of fired stones, domestic artefacts, and small quantities of raw material for artefact manufacture. This area is interpreted as an area for turtle and fish cooking and consumption, with other domestic and industrial activities peripheral to this. Pigeot argues that the main reason for the occupation of this site was to capture turtles, and that fishing was a natural secondary subsistence activity. In this interpretation, the entire cultural deposit at C50 represents one relatively brief and seasonal occupation.

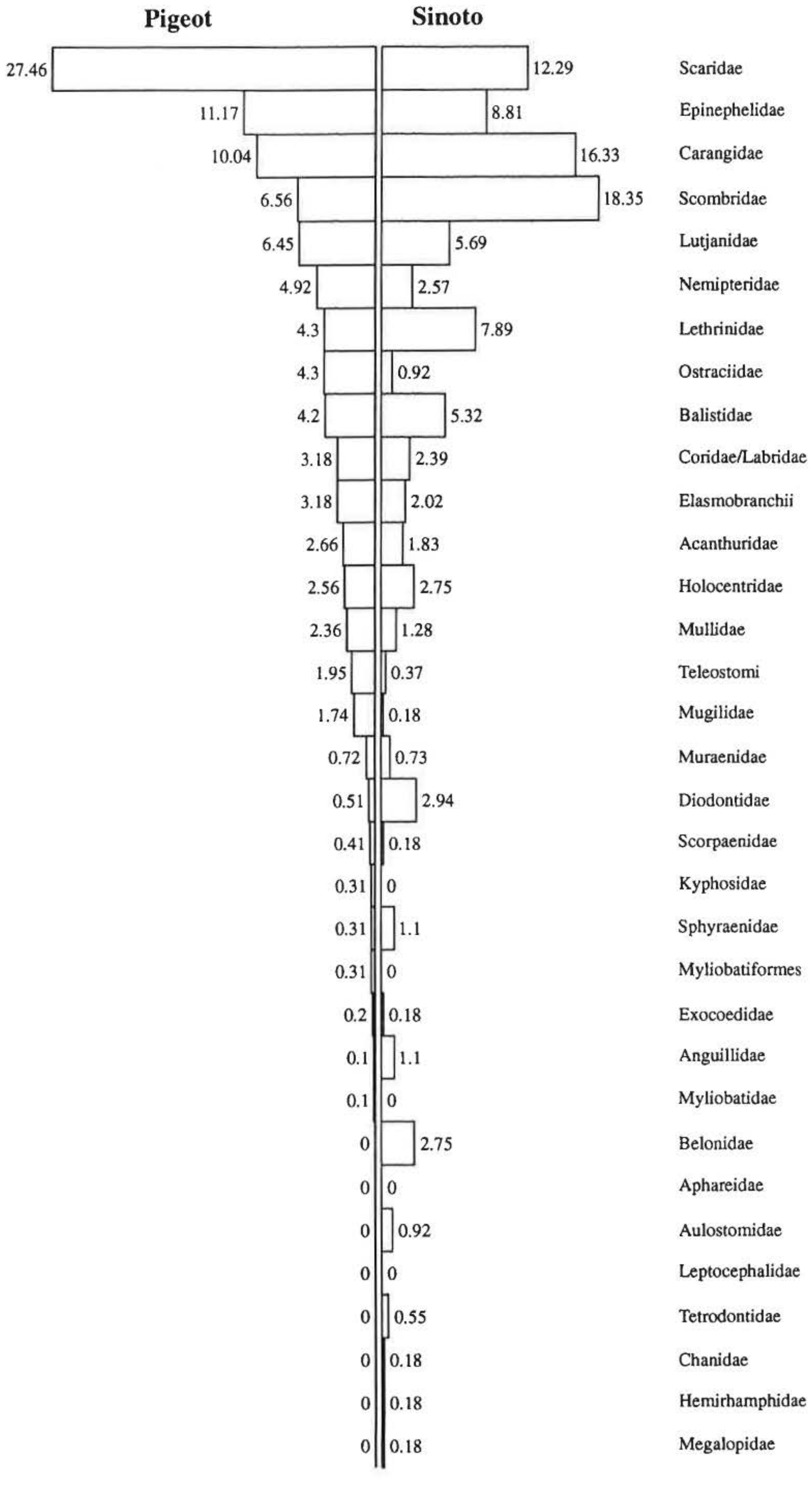


Figure 42: The relative abundance of fish families from Sinoto's and Pigeot's excavations at Fa`ahia.

Other interpretations include the possibility of differential social distribution of tuna in the site. This issue is compounded by the lack of caudal bones identified in the Sinoto material. Tuna are considered to be high status food in many parts of the Pacific. However, although people of rank are responsible for allocating food, this is usually done so everyone gets a share. The social hierarchies which developed in parts of East Polynesia may not have followed such a principle. Dye (1990) suggests that a small group of people in the Marquesas monopolised offshore fish and fishing in the protohistoric period. Kellum-Ottino also comments that the impressions gained by early European observers in the Marquesas may have been coloured by the numbers of prohibitions associated with fishing, and that prestigious fish caught were the property of chiefs (cited in Davidson, Fraser *et al.* n.d.: 7). Te Rangi Hiroa's (Buck 1930) account of Samoan culture also describes distribution of different portions of some fish, including tuna and shark, according to rank (Figure 32). The difference observed in these two excavations could therefore reflect sociological differentiation in the site. Unfortunately, insufficient is known about the site as a whole to decide between the various alternative explanations at this point.

Motupore

Background

Motupore is an island located in Bootless Bay, about 650 m from the mainland of Papua New Guinea and 16 km east of Port Moresby (Figure 43). The archaeological site is situated at the north-eastern end of the island behind a shallow bay, and is fronted by a sand beach and tidal spit (Allen 1978) (Figure 44). Motupore is surrounded by a fringing reef, which provides the habitat for a variety of fish and shellfish. The waters of Bootless Bay, which are expansive and protected from high seas by a barrier reef at the mouth, also contain abundant marine resources, including tuna, turtle, and in the past, dugong and crocodile (Allen 1978: 48).

Fish bone collections from two series of excavations are considered here. The first series took place during 1970-1975 as part of the archaeological field work of the University and were directed primarily by Allen (1978). Between 1970 and 1975 Allen (1978: 51) estimates that under his direction 170 square metres were excavated,although this is thought to represent only approximately 1% of the site. In most areas material was retrieved through the use of 3/16

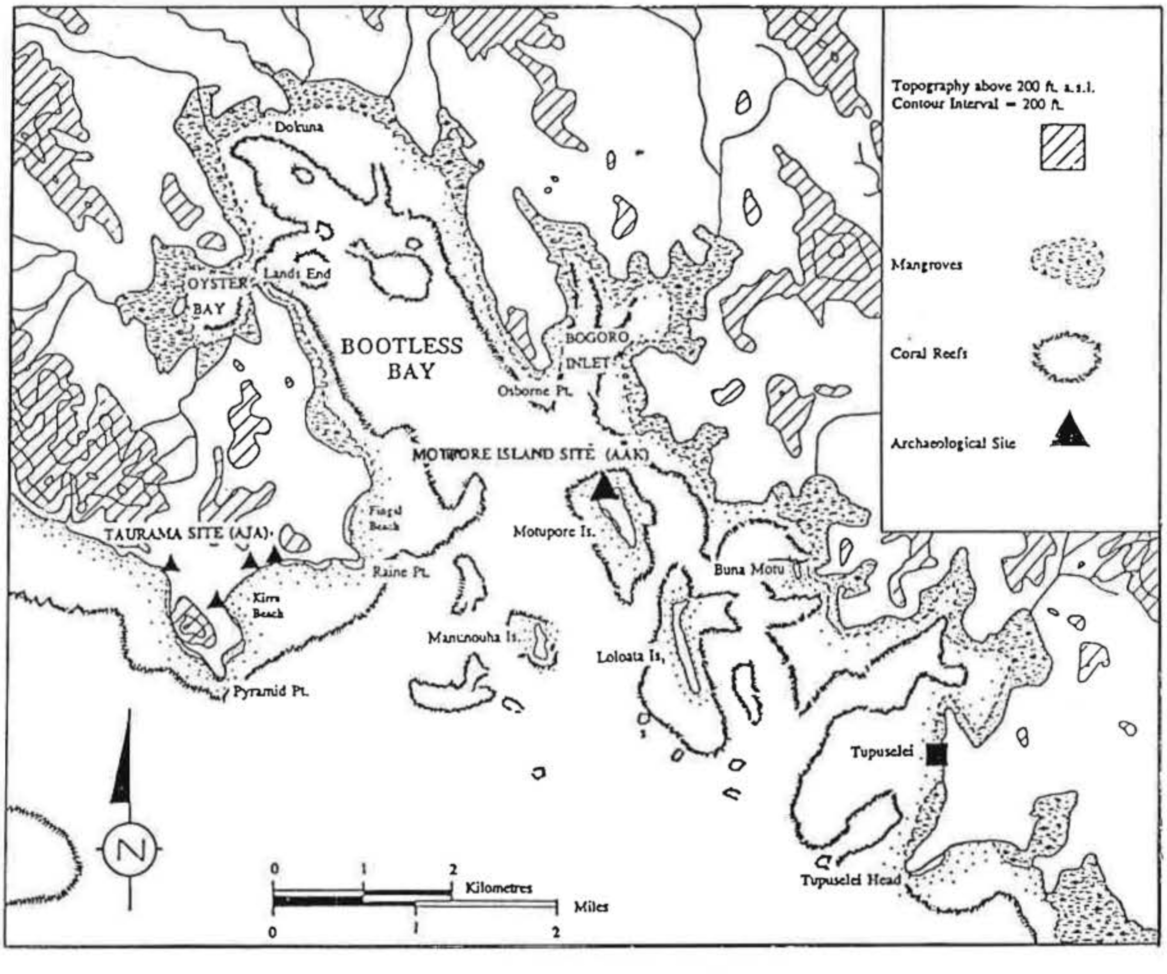


Figure 43: Bootless Bay, Papua New Guinea, showing the location of Motupore and the surrounding environment (from Chatan 1992: 21).

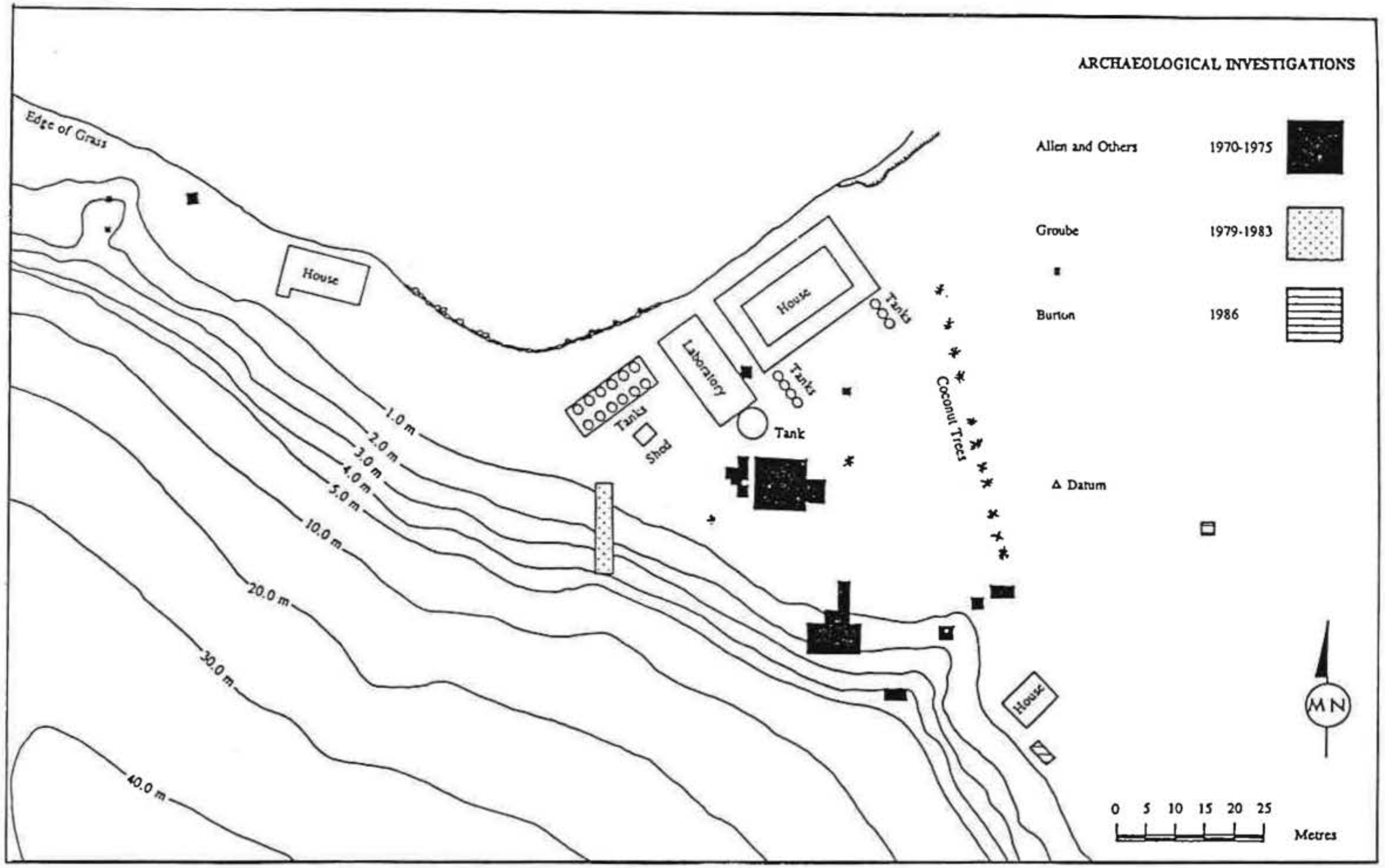


Figure 44: Plan of the Motupore site, showing areas excavated by Allen and Groube (from Chatan 1992: 28).

to 1/2 inch mesh sieves. The site is notable for the huge numbers of artefacts recovered and the deeply stratified midden deposits, indicating intense human activity in the area. Radiocarbon dates from the excavations suggest that the site was occupied for around 450 years, from the beginning of the 13th century AD until well into the 17th century AD (Allen 1978: 51). The second series of excavations were directed by Groube, and took place in a different area of the site (see Figure 44). The results of Allen's original analysis of the fish bone were published in 1986 (Allen 1986); this collection was subsequently re-analysed by McMurtry (1986) using the techniques described in Leach (1986). Fish bone recovered from Groube's excavations was analysed at the Museum of New Zealand Archaeozoology Laboratory (Chatan 1992).

Results

A total of 24 fish families were identified in the fish bone collection from Allen's excavations (McMurtry 1986). Allen's excavations included squares which were able to be integrated chronologically and stratigraphical, and those which could not be. Thus the results are grouped in terms of integrated squares (early and late) and non-integrated squares. These results are shown in Table 12.

The most abundant fish caught were parrotfish (20%), with other major contributions made by Acanthuridae, Balistidae, Scombridae, Coridae/Labridae and Tetradontidae. Together these fish make up 77% of the collection. Another feature of the collection is the large number of families (10), which together contribute less than 3% to the total catch. The results from the analysis of Groube's collection are shown in Table 13. The composition of this collection is very similar to Allen's, again parrotfish are important, with other contributions made by Labridae, Lethrinidae, Balistidae, Diodontidae and Acanthuridae. Tuna, however, occur at lower abundance than in the collection excavated by Allen.

The tuna identifications are listed in Table 14. Both cranial elements and caudal bones are present, with the latter occurring in slightly higher proportions. The shape of the centrum on the penultimate vertebra is round; this contrasts with observations made during the analysis of the previous sites, where the shape of the tuna centra were predominantly oval.

Table 12: The relative abundance of fish families at Motupore, Integrated and Non-Integrated Levels from Allen's excavations (from McMurtry 1986).

	Late		Early		Non-integ		Total	
Family	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Scaridae	76	17.2	43	20.3	112	20.4	231	19.2
Lethrinidae	68	15.4	18	8.5	75	13.7	161	13.4
Acanthuridae	49	11.1	16	7.6	55	10.0	120	10.0
Balistidae	40	9.1	24	11.3	55	10.0	119	9.9
Thunnidae/Katsuwonidae	41	9.3	16	7.6	44	8.0	101	8.4
Coridae/Labridae	33	7.5	24	11.3	44	8.0	101	8.4
Tetrodontidae	43	9.7	14	6.6	31	5.7	88	7.3
Serranidae	20	4.5	15	7.1	22	4.0	57	4.7
Diodontidae	19	4.2	11	5.2	21	3.8	51	4.2
Lutjanidae	11	2.5	8	3.8	23	4.2	42	3.5
Carangidae	8	1.8	5	2.4	22	4.0	35	2.9
Elasmobranchii	8	1.8	5	2.4	19	3.5	32	2.7
Nemipteridae	5	1.1	4	1.9	11	2.0	20	1.7
Plectorhynchidae	6	1.4	5	2.4	5	0.9	16	1.3
Sphyraenidae	0	0.0	3	1.4	3	0.6	6	0.5
Zeidae	4	0.9	0	0.0	1	0.2	5	0.4
Muraenidae	4	0.9	0	0.0	1	0.2	5	0.4
Istiophoridae/Xiphidae	3	0.7	1	0.5	1	0.2	5	0.4
Mullidae	1	0.2	0	0.0	1	0.2	2	0.2
Belonidae	1	0.2	0	0.0	0	0.0	1	0.1
Holocentridae	1	0.2	0	0.0	0	0.0	1	0.1
Katsuwonidae	0	0.0	0	0.0	1	0.2	1	0.1
Coryphaenidae	1	0.2	0	0.0	0	0.0	1	0.1
Platacidae	0	0.0	0	0.0	1	0.2	1	0.1
Totals	**442**	**100**	**212**	**100**	**548**	**100**	**1202**	**100**

Table 13: The relative abundance of fish families at Motupore, Groube's excavations (after Chatan 1992).

Family Name	MNI	%	
Scaridae	223	22.28	± 2.6
Coridae/Labridae	120	11.99	± 2.1
Lethrinidae	110	10.99	± 2.0
Balistidae	84	8.39	± 1.8
Diodontidae	74	7.39	± 1.7
Acanthuridae	68	6.79	± 1.6
Lutjanidae	53	5.29	± 1.4
Tetrodontidae	47	4.70	± 1.4
Serranidae	46	4.60	± 1.3
Scombridae	39	3.90	± 1.2
Carangidae	34	3.40	± 1.2
Elasmobranchii	33	3.30	± 1.2
Nemipteridae	19	1.90	± 0.9
Ostraciidae	12	1.20	± 0.7
Plectorhynchidae	10	1.00	± 0.7
Sphyraenidae	6	0.60	± 0.5
Belonidae	3	0.30	± 0.4
Muraenidae	3	0.30	± 0.4
Mullidae	3	0.30	± 0.4
Scorpaenidae	3	0.30	± 0.4
Coridae	2	0.20	± 0.3
Teleostomi	2	0.20	± 0.3
Myliobatidae	2	0.20	± 0.3
Zeidae	2	0.20	± 0.3
Holocentridae	1	0.10	± 0.2
Echeneidae	1	0.10	± 0.2
Dasyatidae	1	0.10	± 0.2
Total	**1001**	**100**	

Table 14: Number of identified elements of tuna from Motupore, both excavations.

Anatomy	*Allen (NIE)*	*Groube (NIE)*
Left Dentary	12	4
Right Dentary	25	4
Left Articular	3	-
Right Articular	-	4
Left Quadrate	7	-
Right Quadrate	5	-
Left Premaxilla	8	2
Right Premaxilla	15	-
Left Maxilla	5	-
Right Maxilla	1	1
Caudal Peduncle	38	24
Vertebra	219	36
Total	**338**	**75**

Neither sets of results show significant temporal change; however, its appears that tuna bones are not distributed evenly through the site, but occur in greater numbers in the area excavated by Allen. This distribution may parallel the findings on Huahine.

Fishing at Motupore

The structure of the fish catch at Motupore indicates that fish from a wide range of marine environments were being caught. Fish found in shallow reef waters are well represented; these include parrotfish, surgeon fish, triggerfish and puffers. Also present are demersal families, particularly Lutjanidae, Serranidae and Coridae/Labridae. The collections also contain a number of fish families associated with pelagic waters. Tuna was the most important, also present are a few individuals from the Carangidae, Sphyraenidae, Coryphaenidae, Istiphoridae/Xiphiidae and Belonidae families.

On the basis of ethnographic evidence from elsewhere in the Pacific, and from knowledge of fish behaviour, it would appear that the people of Motupore were using a range of fishing technologies, including hook and lines and nets, to catch fish. However, based on ethnohistoric and archaeological evidence from this region McMurtry (1986) argues that the majority of fish in the site, including carnivorous demersal and pelagic species usually taken on lines, were mostly likely to have been caught with nets. McMurtry bases his argument around ethnohistoric evidence about the Motu people which describes a range of netting strategies used for fishing, but not the use of fish-hooks, lures or gorges. Archaeological evidence is also used to support this argument. No fish-hooks or material culture associated with their manufacture were recovered during Allen's excavation. However, bivalves without the umbo frequently occurred in the site. These are used into the present day as net weights, and are believed to have been used as such in the past (Allen 1986: 66). Other methods which may have been used separately or in conjunction with nets, but are likely to be invisible archaeologically, are poisoning, spearing and trappping. These two methods would not be appropriate for tuna though.

Given the focus at Motupore on inshore fish, likely to have been taken with nets, the presence of Scombridae in the site is surprising. Tuna contribute nearly 9% of the MNI for Allen's collection. The presence of these fish in such numbers at Motupore suggests a particular strategy existed to catch these fish. Although they were often caught with a lure in the Pacific, this is not believed to have been the case at Motupore. Several ethnographic accounts describe specialised netting techniques which are used to capture tuna (Oram 1977, Pulsford 1975) and other large fish such as barramundi (Groves 1963) at different times of the year in this region..

Chatan's (1992) study of late prehistoric fishing on Motupore utilises results from several studies of the fish bone recovered from Motupore including McMurtry's and Chatan's own analysis of fish bone from Groube's excavations (Table 13). On the whole, the results are consistent with those previously discussed for the site, and support an approach to fishing centred around netting techniques and strategies. Neither set of results shows significant temporal change, indicating continuity in the exploitation of fish, marine environments and strategies used.

The relative proportions of tuna identified from Groube's excavations, however, are lower than in Allen's. Furthermore, Chatan (1992: 144-145) argues for a greater emphasis on near shore and reef taxa in Groube's collection, while in Allen's collection there is a greater emphasis on open water pelagic species. Chatan hypothesises that the difference in the fish data in terms of reef versus open sea taxa may point to differential access to fish resources, and the specialisation of some social groups towards offshore fish taxa. Fish such as Scaridae, Labridae and Lethrinidae are likely to be important sources of protein for people in the site. They are found in reef edge, lagoon and reef flat areas and are available all year round. Migratory, open water fish including tuna have a limited distribution both temporally and geographically. Chatan suggests that control of the areas where tuna were netted may have been dominated by corporate groups which controlled procurement locations, had ownership of the required technology, possessed specialised fishing skills and could provide the required labour.

Pacific perspectives

Analysis of fish bone collections from Hane, Te Anapua, Vaito`otia and Motupore has been informative on the nature of fishing in sites where tuna are present in relatively high abundances. It is suggested that in these sites, specific strategies directed towards tuna were being practised.

Several other sites in the Museum of New Zealand database contain relative abundances of tuna by MNI at levels between 5% and 10% of the total catch (see Figure 11). The two Polynesian outliers of Kapingamarangi and Nukuoro have MNI of tuna of 5% and 7% respectively. Studies of contemporary fishing practices on Kapingamarangi document several methods for catching tuna, including trolling with lures, and a specialised strategy for sub-surface tuna (Leach and Ward 1981, Lieber 1994). The efficacy of these methods is attested to on Kapingamarangi; when specimens were being collected for a comparative collection two species of Scombridae, yellowfin tuna and wahoo, were the first fish caught (Leach and Davidson 1988: 4). By comparison, rainbow runner, also a pelagic species greatly favoured by fishermen, was one of the last fish caught. The argument that pelagic fish were often the subject of stories in the men's house, but not often caught in reality would appear to be the case for some species more than others. Of the 24 fish families which are present in archaeological assemblages from Kapingamarangi, only 10, including tuna, are considered to have been of economic importance (Leach and Davidson 1988: 5). This is believed to represent a specialised approach to fishing, directed at a limited range of fish.

Although often caught using pearl shell lures, it appears that on Nukuoro tuna were primarily fished for using one-piece hooks (Leach and Davidson 1988). There is a decline in the relative abundance of tuna, 12.5% to 4.9%, in sites on Nukuoro. The increase through time of netted and other foraged fish species and those caught using baited hooks, in conjunction with a decline in pelagic fish, indicates a trend towards more generalised fishing strategies (more even emphasis on a large number of dominant fish) (Leach and Davidson 1988: 15). In the archaeological record on both islands tuna contributes to the catch, but is not a dominant component. A similar position can be observed in contemporary fishing practices; although specific methods exist for the taking of tuna it is not a primary focus of the fishing effort all year round.

The scarcity of tuna in sites is also often consistent with the predominance of inshore fish in economic importance, with offshore and pelagic fish present in only in small numbers. The occupants of such sites appear to directed their efforts primarily to towards inshore waters, and probably did not spend much time offshore. One exception to this occurs at Mochong, a site on Rota, in the Marianas. The catch of the prehistoric people of Mochong includes numbers of offshore pelagic predators such as marlin, swordfish and dolphinfish (Leach *et al.* 1988). Given these people's knowledge of, and success in catching, such offshore species it could be expected that tuna would also feature in their fishing strategies. This is not borne out by analyses of archaeological assemblages, where tuna contributes less than 1% of the total catch. It appears that the people of Mochong developed specialised strategies to catch dolphinfish and marlin, that successfully targeted these fish to the exclusion of other pelagic predators. Strategies based on lures and bait-trolling are suggested for dolphinfish, and harpoons for marlin (Leach *et al.* 1988).

A low occurrence of tuna in sites is considered to be indicative of opportunistic catches of this fish, either caught using methods which are aimed at other kinds of fish, or by taking advantage of chance encounters. Linguistic evidence has been used to demonstrate that the speakers of early Oceanic languages were aware of, and had names for, a variety of fish found in all the marine zones, and possessed the technology to catch them (Walter 1989: 143). On linguistic grounds it is considered difficult to argue for any major differences between the practices of early Oceanic fishers and those of more recent times. The ability to catch tuna systematically is nonetheless subject to a range of constraints, not the least being seasonal fluctuations in natural abundance of the fish itself. Other factors include the access to technology and fishing grounds and labour requirements. The presence of tuna remains in sites in the Pacific, albeit in varying levels, and the antiquity of linguistic terms associated with this fish and fishing activity, attests to the awareness prehistoric people throughout the Pacific had of tuna. It is likely that given the opportunity, these fish would be caught.

6: The economics of prehistoric fishing for tuna

The activity of fishing for tuna in some Pacific island cultures has many and varied layers of meaning, and involves both cultural and economic variables. Its importance as a social activity in Pacific island communities has been documented in previous chapters. Tuna is also a source of food, and as such can be viewed as a component of the subsistence economy. The existence of ritual behaviours to facilitate the continued arrival of tuna in Doubtless Bay by the Motu people (Pulsford 1975) can be seen in part as an indication of their importance as a food source in the local economy. Ritual prohibitions associated with tuna fishing expeditions to ensure good catches are present in other parts of the Pacific (see Akimichi 1986, Dye 1983, Lieber 1994) and have been recorded in earlier ethnohistoric accounts (Nordhoff 1930). The status accorded to successful tuna fishermen is in no small way a function of the desirability of the catch as a food, as well as the risk and skill involved.

The purpose of this chapter is to investigate the economic aspects involved in fishing for tuna, focusing in particular on the archaeological sites of Hane, Te Anapua, Fa'ahia and Motupore. Subsistence economies are sometimes described in terms of return for effort, or costs, risks and returns (Colley 1990). Models based on "optimal" strategies adopt commercial theories which assume behaviours are oriented around the highest return, which often has a commensurately high risk factor. However, studies of subsistence economies have found that this type of model does not always explain the economic choices people make (Clarke 1968: 94-95). In actuality a combination of strategies are used which may not necessarily provide the best returns, but minimise or reduce risk and uncertainty. Ideally a range of information is required to investigate the appropriateness of such models to explain subsistence behaviour. These include the dietary contribution made by different resources in the economy, the time and energy required for their procurement and delivery, any risks or constraints involved, and also distribution and consumption patterns.

Given the nature of the archaeological record, detailed information of this kind is often unavailable. Nevertheless, it is still possible to examine several aspects of fishing for tuna as food in the Pacific with the intention of increasing our understanding of the economics involved. Within the context of this study the dietary merits of tuna will be contrasted with those of other marine fish present in archaeological sites. In order to do so nutritional information will be reviewed, the size of tuna from the archaeological sites of Hane, Te Anapua, Fa'ahia and Motupore will be estimated, and the return for effort involved in tuna fishing as opposed to other fishing strategies will be considered.

Tuna as food

Fish and marine resources are important components of Pacific island diets primarily as sources of protein, and essential fats. The contribution made by these resources depends on a variety of factors, such as availability, technology and also cultural beliefs. The role of cultural as opposed to ecological or technological factors in the selection of fish for food is however not often visible in the archaeological record. Dietary preferences may be personally or communally expressed, and involve a number of contributing factors including taste, nutrition, beliefs and customs. One instance where social values have been identified in the archaeological record occurs in the practice of food avoidance behaviour. Several kinds of fish, such as eels, sharks, puffer fish and porcupine fish, have at various times been considered unacceptable as food in some parts of the Pacific (Leach *et al.* 1996a: 335). The scarcity or absence of the remains of these fish in particular archaeological sites has been argued to have resulted from the practice of such behaviour (Kirch and Yen 1982, Leach 1996, Leach and Davidson 1988, Leach *et al.* 1988). In the Pacific today the desirability of tuna as a food is in no small way due to its taste and texture. This has been documented in various modern reviews (Gillet 1987: 6, Gillet and Toloa 1987: 183, Titcomb 1972: 61,87), and it is reasonable to assume that this was also the case in the past.

Table 15 shows the composition of some tuna species found in the Pacific, several other common fish families and land mammals and birds in terms of nutritional values of protein and energy/100g of flesh. This shows that, as well as tasting good, tuna possess relatively high levels of protein. Tuna have a high red muscle ratio which facilitates their fast swimming ability, and this is reflected in the high protein value. Compared to parrotfish, a mainstay of the Pacific diet in many areas (Fleming 1986), skipjack provide more than 1/5th more protein per 100g of flesh. Tuna also rates favourably with other sources of protein, including pigs.

Table 15: Nutritional composition of tuna and other Pacific island foods.

(Sources: 1= Sidwell *et al.* 174; 2= Hongo *et al.* 1993; 3= Milligan *et al.* 1988; 4= Smith 1985; 5= Anon. 1983; 6= Vlieg 1988.)

Taxa:	**Protein (g/100g)**	**Energy (kcal/100g)**	**Source:**
Bonito (*Sarda sp.*)	24.7	-	1
Spanish mackerel (*Scomberomorus sp.*)	18.9	103.4	1
Skipjack	25.5	-	1
	23.4	176	6
Yellowfin	24.3	-	1
Albacore	24.2	134	1
	26.2	148	3
Groupers (Serranidae)	19.2	-	1
Jacks (*Caranx sp.*)	19.9	96.6	1
Parrotfish (Scaridae)	19.7	105.0	1
Snapper (Lutjanidae)	19.2	99.5	1
Coral reef fish (lean)	17.0	73	5
Coral reef fish (fatty)	19.0	166	5
Pig	18.4	230	2
Dog	21.0	126	4
Chicken (roasted dark meat)	23.1	155	3
Pigeon (various species)	21.7	129	2
Turtle	16	79	5

Compared to other fish families tuna are also a good source of energy. This can be attributed in part to the high levels of oil (lipids) contained in these fish. Figure 45 shows the oil /100g for several species of tuna and fish families commonly found in Pacific archaeological sites. Albacore and bonito in particular contain high levels of oil. The distribution of oil in the body of tuna is not uniform. Figure 46 breaks down the distribution for several areas of the body. The relatively high proportion in the head may account for the fragility of the cranial anatomy as opposed to the robustness of the caudal bones found in archaeological sites. The high oil content of the oilfish (*Ruvettus sp.*) has also been suggested as a reason for its absence in archaeological sites (Severance 1986:38).

Figure 46 also provides data for several fish species found in New Zealand waters, in the absence of comparable data from the Pacific. This shows that the proportion of fat in fish body parts is variable across species. The distribution of portions of fish in Samoan communities appears to have some corollary with this characteristic. Te Rangi Hiroa's (Buck 1930: 124-5) records of food habits in Samoa describes the division of tuna and shark, and their distribution according to the status of the recipient (Figure 32). The best portion of tuna is considered to be the head, and of the shark it is the stomach and intestines. These body parts are both high in oil. Whether or not this pattern of distribution is a function of taste or nutrition or a combination of both is difficult to say.

Estimation of tuna size

Studies of prehistoric subsistence in the Pacific region tend to characterise resources in terms of high level taxonomic groups such as bird, fish, mammal, shellfish. The range of abundance measures used to quantify these faunal remains in sites include counts of the numbers/amounts of bones in sites (bone weights or NISP) or in relative numbers of taxa, using generated figures such as MNI. These figures can then be examined to enable a comparison of the relative abundances of these groups through time, and hence any changes to the economy. This kind of analysis does not, however, address the contribution made by different resources in terms of food yields. Essentially, the food value of one pig is considerably different from that of one fish, in terms of both quantity and nutrition. Consequently, studies have been undertaken which attempt to calculate food values in terms of meat weights and/or caloric values.

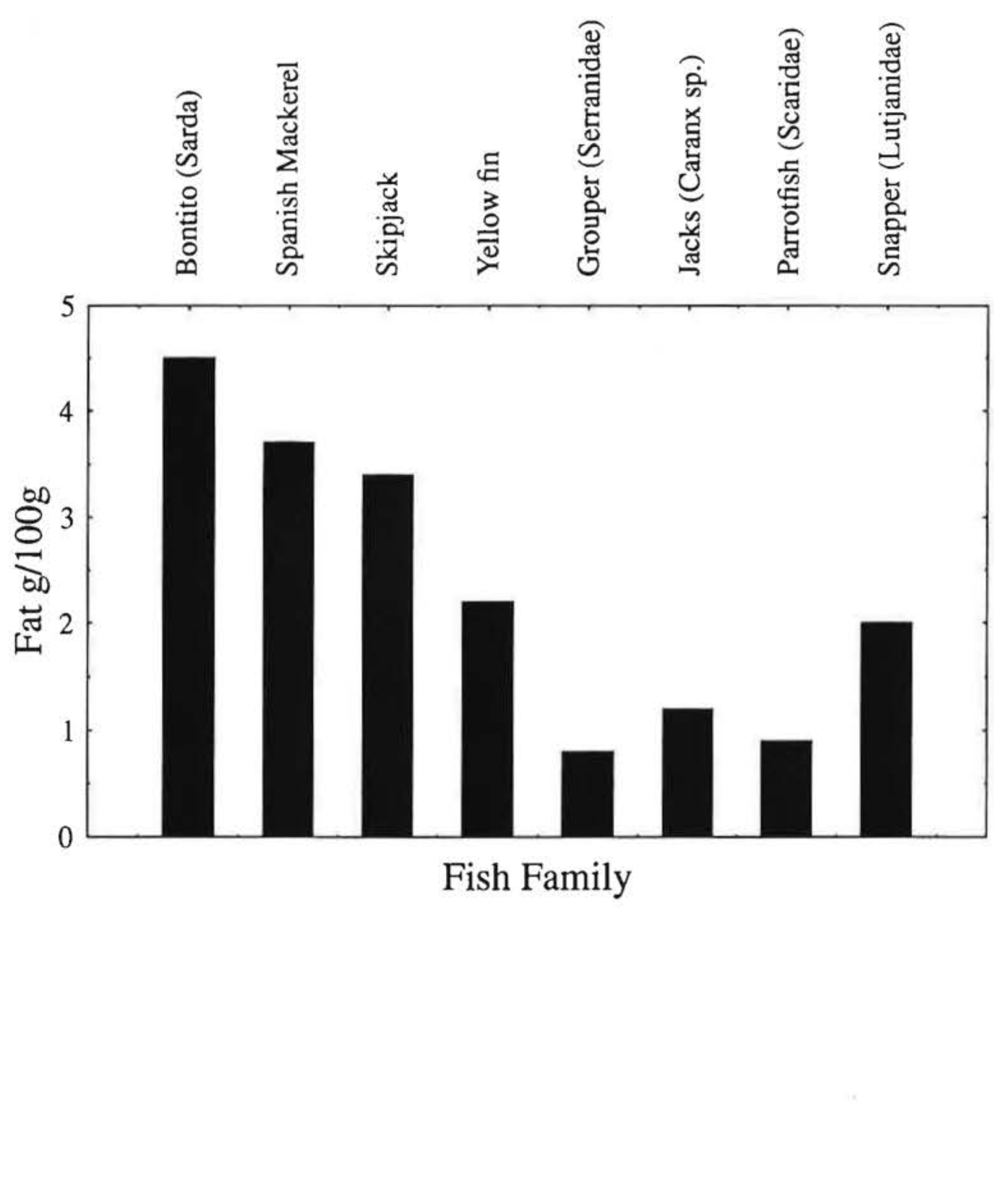


Figure 45: Levels of lipids in various Pacific fish families (source Sidwell *et al.* 1974).

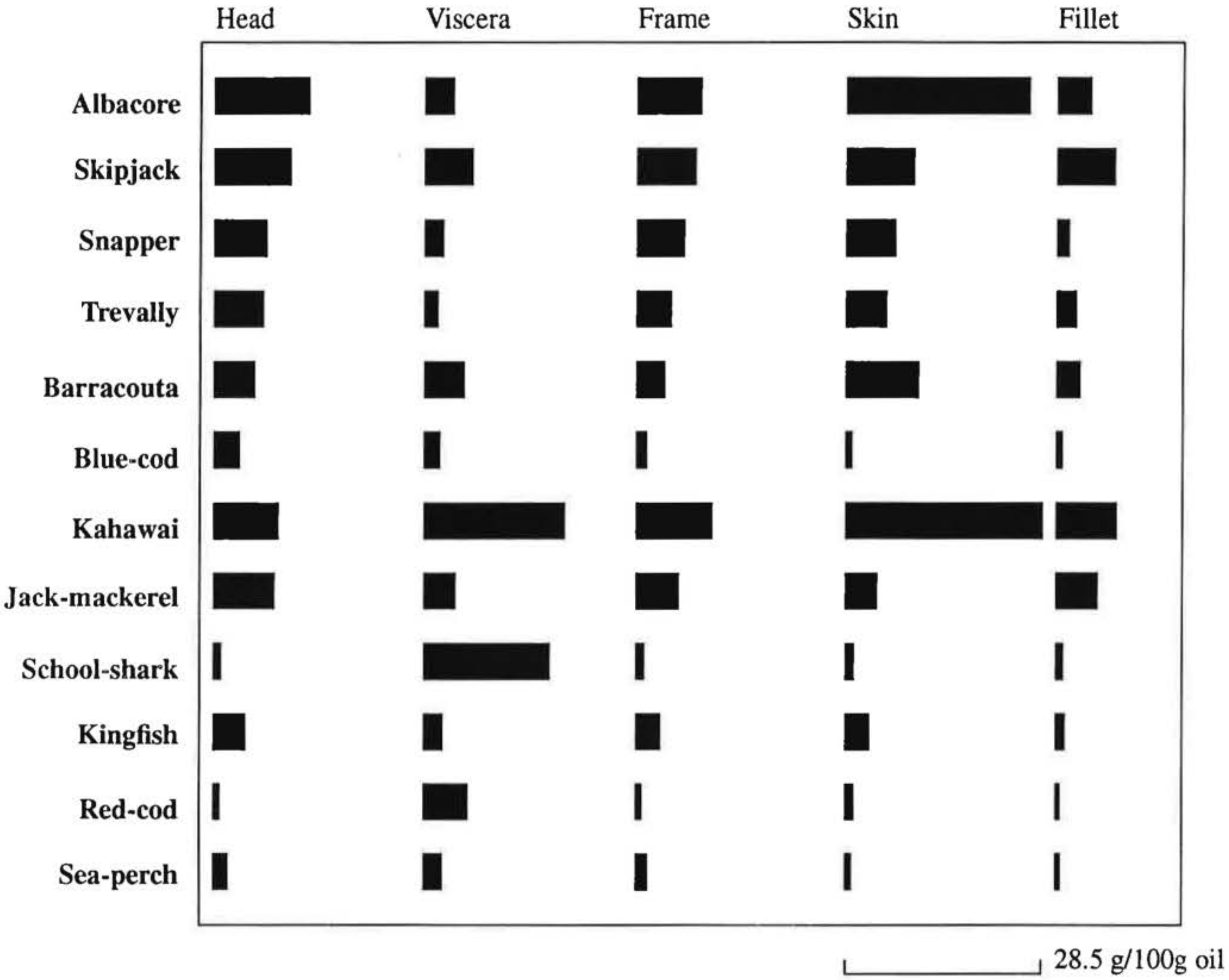


Figure 46: Distribution of lipids across body parts (source Vlieg 1988).

At this time little work has been undertaken which addresses the relative economic contributions of different species within these basic food groups. Dye's (1990) analysis of fishing in the Marquesas identified an apparent decline in offshore fish as opposed to inshore species. However the data used (Number of Identified Specimens) informed on the relative abundance of fish remains in sites, as opposed to the food they represented. The relationship between these two categories is very complicated, and one cannot be used as a substitute for the other. Several sites have been identified in the Pacific region which contain a large proportion of tuna remains. These fish are capable of attaining large sizes on maturity and may represent a significantly greater food yield per individual than most other fish, particularly inshore species, which is not encompassed by measures of abundance such as NISP and MNI. In order to consider the economic returns provided by tuna it is therefore considered important to establish what sizes of tuna were present in archaeological sites. Sites identified in Chapter 5 with sufficient numbers of bones were subjected to metrical analysis to establish size frequency histograms for the tuna catch.

The method employed to estimate the live fish size from archaeological bones follows that developed at the Archaeozoology Laboratory, Museum of New Zealand (Leach and Boocock 1995, Leach *et al.* 1995, 1996b, 1996b, 1997a, 1997c). This method has been applied to a number of fish species found in New Zealand waters which were of particular importance in pre-European Maori fish catches. Fleming (1986) also reconstructed live fish size from archaeological bones using a similar method, in his study of the role of parrotfish (Scaridae) in Pacific prehistory.

The procedure involves two main steps. First, the relationship between fish osteology and fish length (and weight) is established. This is achieved through the metrical analysis of a modern sample and the generation of regression coefficients which describe these relationships. Secondly, the archaeological material is measured, and using the regression coefficients original fish sizes are estimated, and dispersion statistics and size-frequency histograms are produced.

The bones which were used for measurement in this study are the five paired cranial bones (premaxilla, maxilla, dentary, articular and quadrate) and also the ultimate vertebra, which is particularly diagnostic of the Scombridae family. These bones are also those which are used for the identification of tuna from archaeological fishbone collections. Given the often fragile and fragmented nature of archaeological tuna bone, measurements were defined for both whole and incomplete bones. Figure 47 illustrates the measurements taken for each bone.

Following the measurement of bones from the modern sample and their entry on a computer database, it was necessary to establish reliable regression relationships between bone dimension and live fork length. These could then be used for studying the archaeological bones. To this end, regression analysis was carried out on the measurements taking each bone dimension individually, and testing various types of curve fitting procedures to the data. A number of regression models were examined to work out the optimum estimator for each bone measurement.

Measurements were then made of the archaeological tuna bones recovered from the sites of Motupore, Hane, Te Anapua and Fa'ahia. The largest measurement available was taken for each bone following the definitions illustrated in Figure 47, and entered into a database along with the measurement code and provenance information. A somewhat problematic issue arises with the selection of bones for measurement. For example, the MNI for tuna from Hane is 137, however, the number of identifiable tuna bones (which could therefore be measured) is 536. Should the number of measurements made on bones equal that of the MNI for the site and, if so, which bones should be measured? This issue has been investigated using computer simulations to test whether various kinds of samples from a bone collection will produce similar dispersal statistics to those of the original collection (see Fleming 1986, Leach and Boocock 1995). It was concluded that measuring all bones of a species in order to arrive at a size-frequency histogram of the original catch does not introduce bias into the results, so long as the survival rate by bone size was random and the sample is of a reasonable size. Measurements were then converted into estimates of fork length using a computer program.

It has been demonstrated that bone measurements and fish lengths are usually highly correlated, with coefficients which usually oscillate between 0.95 and 0.99 (Leach *et al.* 1996c, Leach *et al.* 1997a, Desse and Desse-Berset 1996). This high correlation has been argued to hold universally for fish bone/fish length relationships (Desse and Desse-Berset 1996: 172). Furthermore, the relationship between bone measurement and fish length is considered to be a general one for species, often valid for genus and occasionally for a whole family as well (Desse and Desse-Berset 1996: 176). For this study a modern sample of 165 albacore (*Thunnus alalunga*) of known fork length were used. Given the lack of variation in

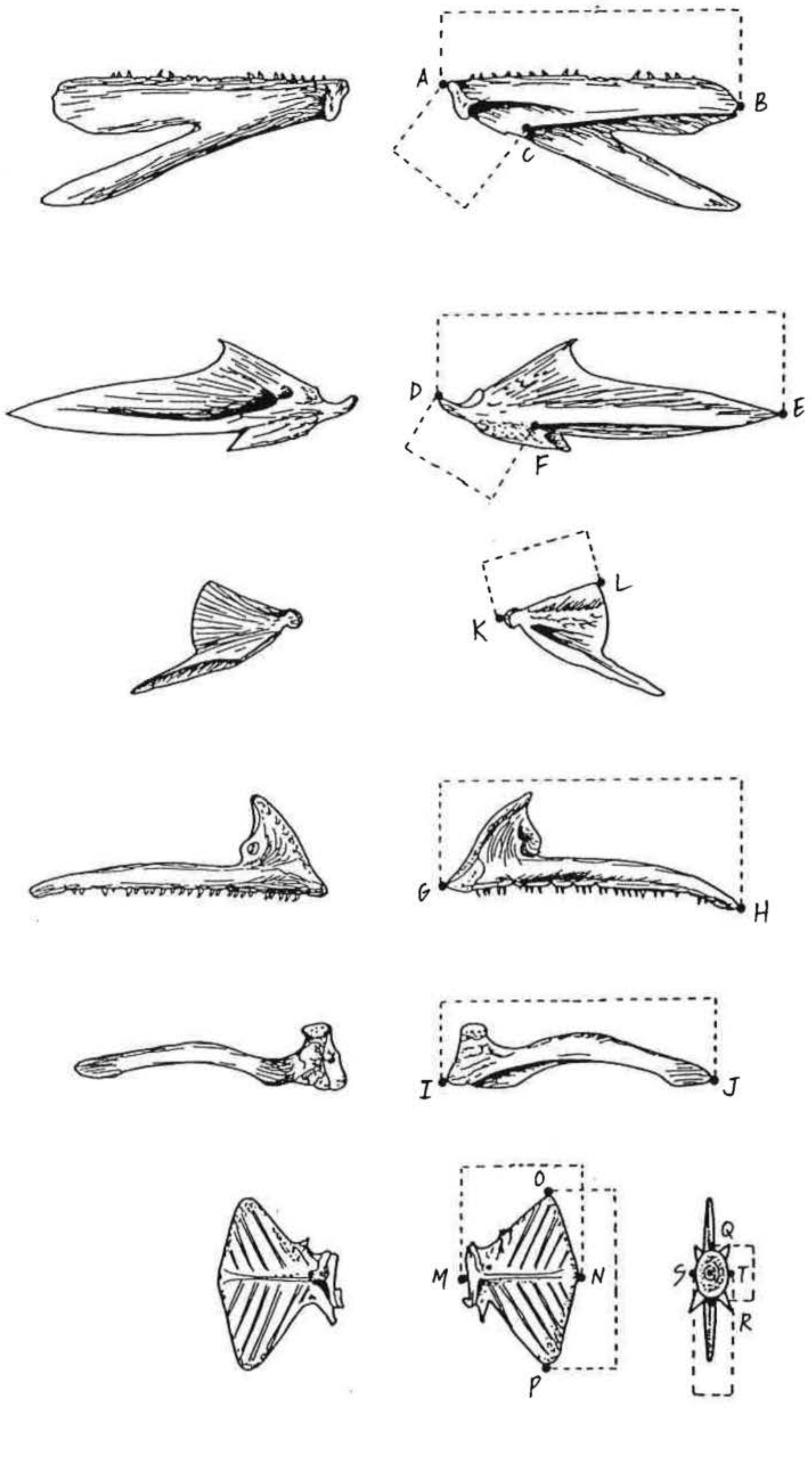


Figure 47: Elements of *Thunnus alalunga* used for measurements. The right cranial bones are illustrated. The measurements were made between A-B and A-C on the dentary; between D-E and D-F on the articular; between G-H on the premaxilla; between I-J on the maxilla; between K-L on the quadrate; and between M-N, O-P, Q-R and S-T on the ultimate vertebra.

the osteology of the Scombridae family, particularly between the higher members, it was proposed that the resulting equations would be able to be applied to the archaeological material, although potentially a number of different species could be present. It should be noted that this is not an ideal procedure, but merely a first step in a research field which will take many years to complete. Ultimately, separate equations need to be developed for each species, and where possible identifications of archaeological bones made to species, to enable the correct equation to be used. Other factors involved the choice of this modern sample included availability and costs.

Several issues arose during the course of the present analysis. Firstly the fragmentary nature of tuna bones recovered from archaeological sites limited the number of measurements possible. Of 1046 potential measurements possible on complete bones, only 521 were able to be taken. This is lower than the rate achieved for other analyses of this kind. Due to the structure of the assemblages from Hane, Te Anapua and Motupore the majority of measurements were made on the ultimate vertebra. It is notable that the regression coefficients for measurements made on the centrum were lower than those obtained for the cranial anatomy. It was also observed that the shape of the centrum on the ultimate vertebra in some archaeological specimens differed from that of the modern sample. In both the modern sample and the majority of the archaeological bones, the centrum was oval, however on some archaeological bones this process was round. The effect of this factor on the size-frequency results is not well understood, but it is possible that given the different proportions the individuals are either biased towards smaller or larger sizes depending on the measurements taken. This observed phenomenon also has implications for identification. Until these issues are better understood the results of this analysis should be considered as preliminary only.

The size frequency diagrams and dispersal statistics for each site are provided in Figures 48-51. The tuna caught at Hane had a mean fork length of 367 ±16mm. The mean size of tuna at Te Anapua was estimated to be 501± 24 mm, and at Fa'ahia 531 ±4mm. The mean length of tuna from Motupore was 724 ±26mm.

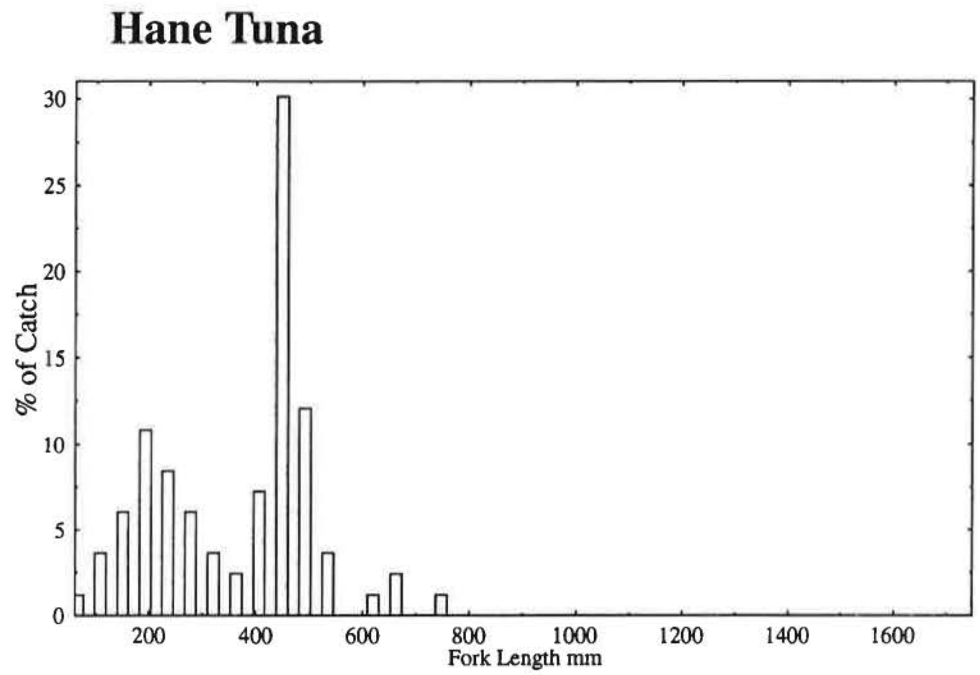


Figure 48: Size-frequency histogram of measurements from Hane.

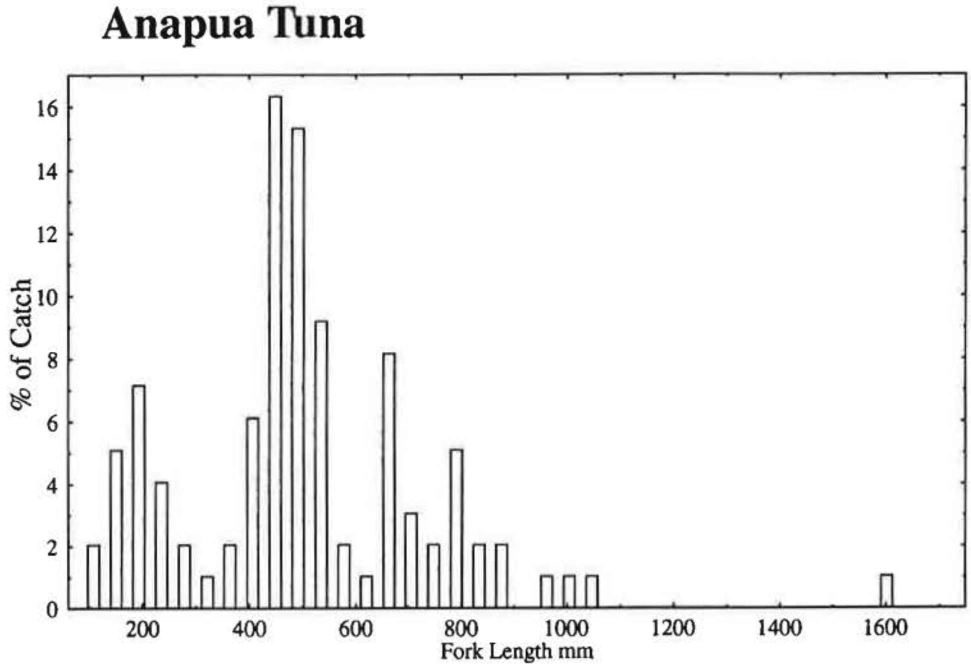


Figure 49:Size-frequency histogram of measurements from Te Anapua.

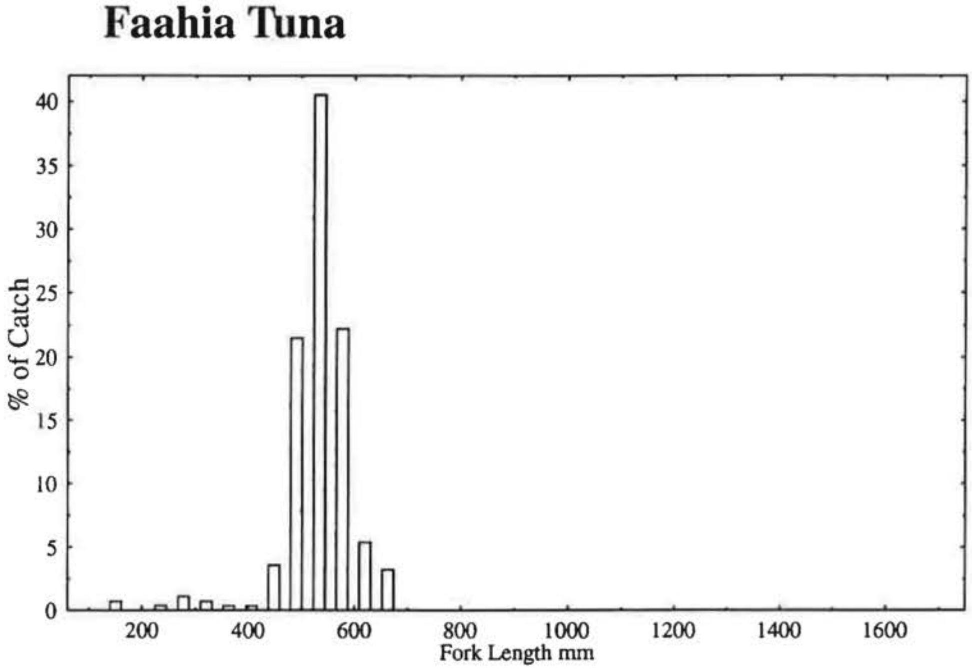


Figure 50: Size-frequency histogram of measurements from Fa`ahia.

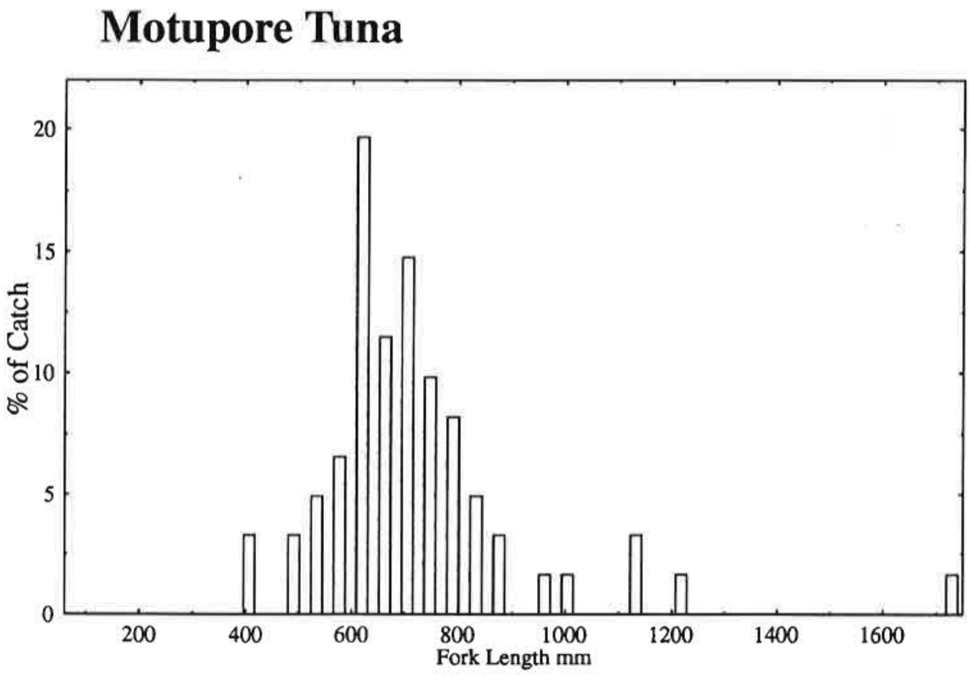


Figure 51: Size-frequency histogram of measurements from Motupore.

A feature of the histograms for Hane, Te Anapua and Fa'ahia are the multi-nodal distributions. There are several possible explanations for this. Tuna are known to form multi-species schools of similar aged fish, by size. Thus the distributions may be representative of tuna catches taken from different schools of similar sized fish of several species. Alternatively, the variations may be a result of different species contributing to the catch. Accounts of offshore fishing in East Polynesia describe catches composed of several kinds of tuna (Gillet 1987, Gillet and Toloa 1987, Nordhoff 1930).

Length frequency data for skipjack and yellow fin obtained during tagging experiments around the Marquesas are shown in Figure 52. There are two distributions for skipjack, with average sizes of around 45 cm and 80 cm. The average size of yellowfin tagged was 60 cm. Figures 53 and 54 give the length frequencies of the commercial yellowfin catch in the Eastern Pacific during 1955-1990 (Tomlinson *et al.* 1992: 376-7). These graphs illustrate the vulnerability of yellowfin of different ages/sizes to different fishing methods depending on their vertical distribution, which is believed to be primarily governed by temperature. Trolling, which is classed as a surface fishing method, takes smaller fish than long-lining, which targets older, larger individuals. Skipjack, and to a lesser extent juvenile yellowfin, are the main species currently taken by small-scale local fishermen. They are mostly caught from small boats trolling and poling using pearl shell lures (Collette and Nauen 1983: 28). It is likely that both these species are represented in the histograms of the archaeological material. Other possibilities include albacore and bonito. The reconstructed size of tuna from Motupore falls within the adult size range for yellowfin, and appears consistent with ethnographic accounts of seasonal fishing for yellowfin in this region.

Hane and Te Anapua have in common a peak at 200 mm. There are no tuna species which are mature at this size in the region; these small fish may be juveniles, possibly of more than one species. It is notable that migrations of skipjack pre-recruits (up to 35 cm fork length) have been hypothesised for the Eastern Pacific (Collette and Nauen 1983: 43). Skipjack in the eastern central Pacific are thought to originate in equatorial waters, pre-recruits then split into a northern group migrating to the Baja California fishing grounds, and a southern group entering central and south American fishing grounds. After remaining there for several months both groups then return to the equatorial spawning areas. Fishermen in the Marquesas Islands are well positioned to take advantage of this seasonal phenomenon. According to contemporary data, the tuna catch is better during the summer months (Bayliff and Hunt 1981:

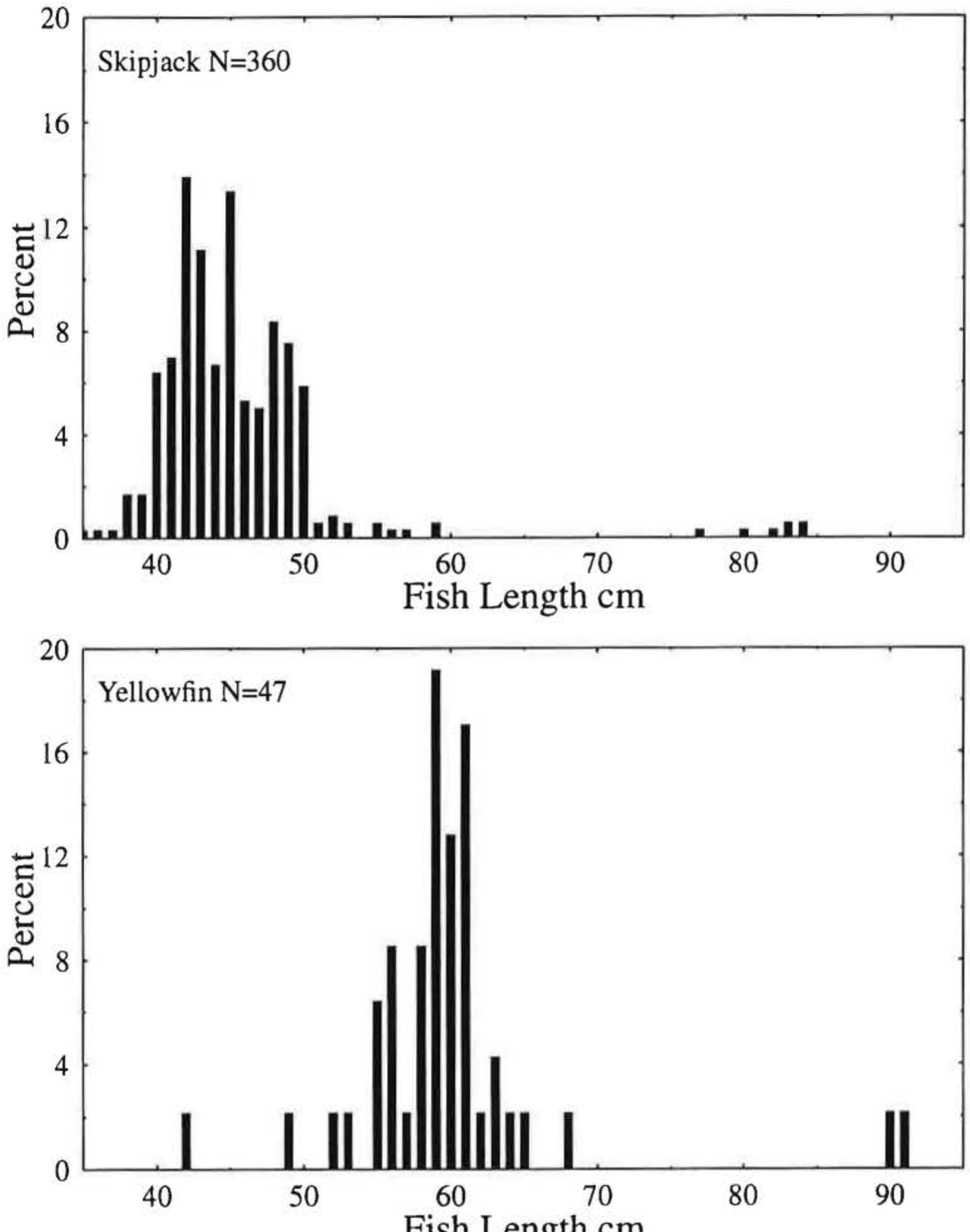


Figure 52: Length frequencies of modern yellowfin and skipjack catches, Marquesas (source Anon. 1978).

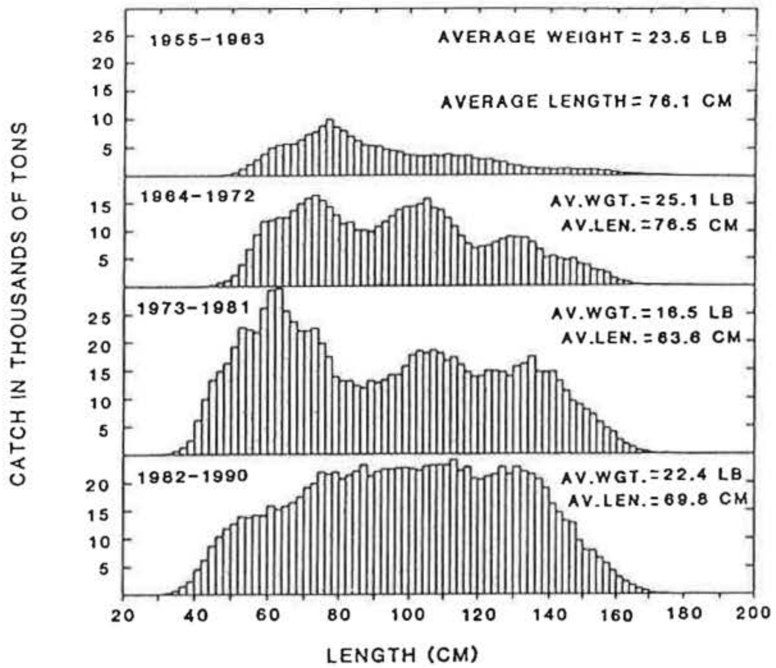


Figure 53: Length frequencies of modern purse-seine catches of yellowfin, Eastern Pacific (source Tomlinson *et al.* 1992: 376).

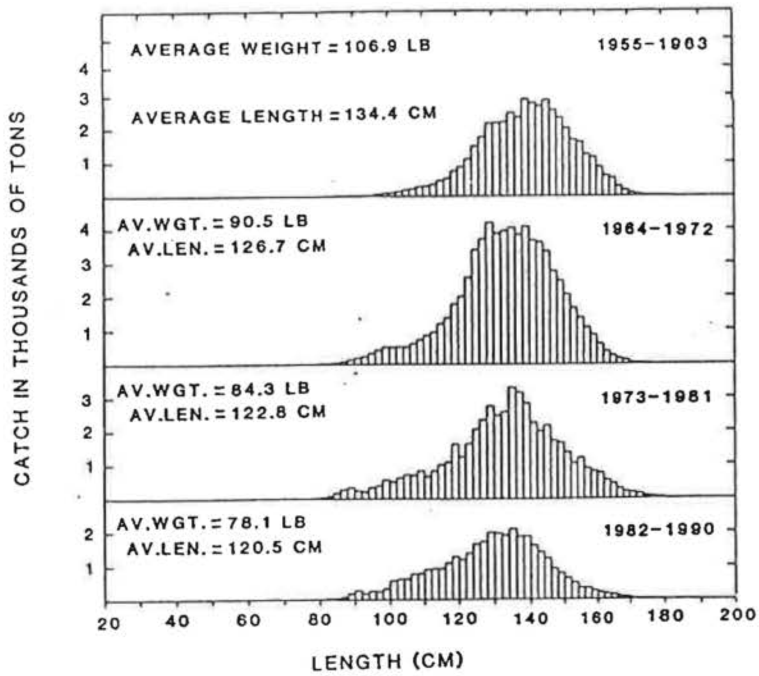


Figure 54: Length frequencies of modern long-line catches of yellowfin, Eastern Pacific (source Tomlinson *et al.* 1992: 377).

11). Tuna fishing in East Polynesia is also predominantly a summer activity, although it is also influenced by sea conditions (Oliver 1974).

Currently, size reconstruction of fish from archaeological sites in the Pacific has only been undertaken for one other fish family, Scaridae, or parrotfish (Fleming 1986); although this type of analysis has also been performed on fish remains found in European sites (Wheeler and Jones 1989, Casteel 1976, Morales and Rosenlund 1979). In order to gain a better perspective on the range of sizes found in the overall fish catch of the selected sites, and hence the relationship of tuna to these, estimations were made of the average size of fish commonly caught in the tropical Pacific using reference books (Munro 1967, Randall *et al.* 1990) and personal observations (Leach pers. comm.). Figure 55 presents the results in graphical form for each site. The estimates are given in Appendix 3. Until regression equations have been established for other fish families and measurements made on archaeological bones from specific sites this kind of comparative exercise provides the only means of evaluating the contribution made by one particular fish against the others in the overall catch. It should be considered a first step only.

The average size of tuna from Hane is somewhat smaller than expected, and as such the majority of tuna caught would probably not have made a greater contribution per fish than any other component of the catch. The same is probably true for the smaller individuals at Te Anapua. Both Te Anapua and Fa'ahia have peaks at around 550 mm, and these fish were probably some of the larger kinds of fish caught, in conjunction with fish such as members of the Carangidae, Serranidae and Lutjanidae families which inhabit waters around the reef edge. The larger individuals at Te Anapua, and also at Motupore, represent quite large fish, particularly in comparison to the sizes commonly attained by inshore species.

Return for effort

It has been demonstrated above that in terms of nutrition tuna are a good source of protein and energy. Even where relatively small sized tuna were being caught, their protein and oil content ensured relatively better dietary returns compared to other kinds of fish. At Te Anapua, Fa'ahia and Motupore tuna were probably on average larger than many of the inshore reef fish caught. Other kinds of return provided by successful catches of tuna are more intangible, but no less significant. These include social values of status and prestige. The effort invested in

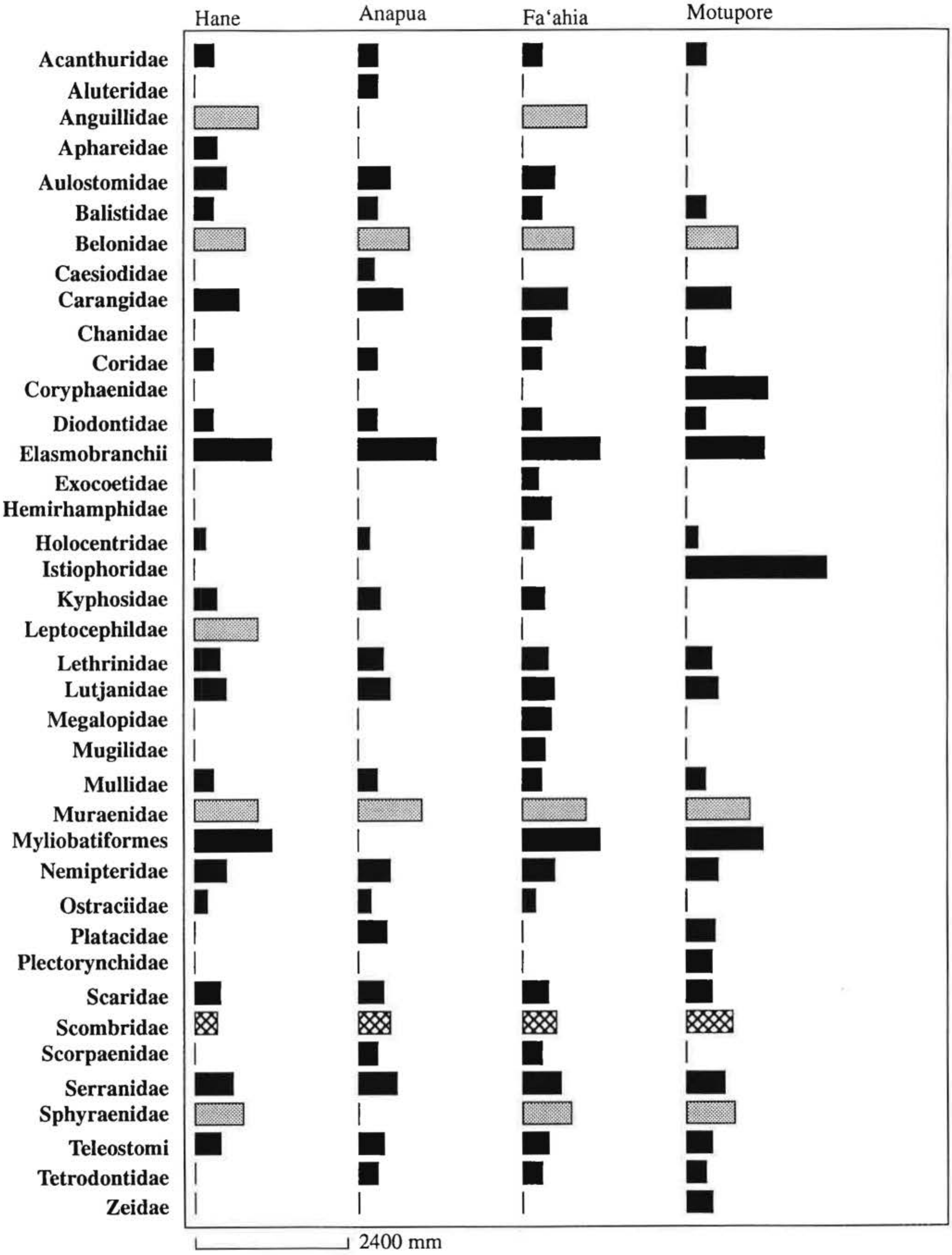


Figure 55: Size estimations for fish families in sites

fishing for tuna, or any kind of fish, in archaeological sites is more difficult to assess. Nevertheless, in terms of pelagic fishing, return for effort may be a factor in explaining the importance of these fish in some sites. The following discussion focuses on two inter-related aspects of effort identified for tuna fishing, these are location time, and the energy involved in landing these fish.

Although the notion of trolling for tuna is a popular one, it is apparent that a diverse range of methods for catching tuna have been utilised in the Pacific. When considering the effort involved there is obviously a difference between catches which are made as part of a generalised strategy targeting a range of acceptable fish, and those which are specifically designed to take a particular kind of fish. The following discussion is primarily concerned with fishing strategies which include tuna as a desired fish, not those where tuna is an opportunistic- or by- catch.

The majority of tuna are open water species, although some prefer inshore waters and can be found along coral reefs edges. The amount of time involved in locating tuna during offshore fishing expeditions is usually highly correlated with a particular aspect of tuna behaviour, that is their tendency to form schools in surface and near-surface waters particularly near islands, seamounts, thermal fronts, current interfaces and floating logs. Traditional tuna fishing strategies utilise detailed knowledge of fishing grounds and tuna behaviour to maximise the location of tuna schools (Gillet 1987, Johannes 1981, Nordhoff 1930, Lieber 1994). Variations in seasonal abundances are also taken into account. The presence of birds attracted by the small fish chased to the surface by feeding tuna is an important indicator of tuna at the surface used by fishermen across the Pacific.

Once located, fishing a school of tuna can be a highly profitable exercise. While on Niuatoputapu Dye (1983) observed that 67 tuna were caught over a period of two hours. Figure 56 shows the numbers of tuna caught during a period of study undertaken by Gillet (1987) in Satawal. The difference between a successful and unsuccessful fishing expedition is clearly shown, but when this data is aggregated (Table 16) the “hit and miss” nature of this activity is obscured.

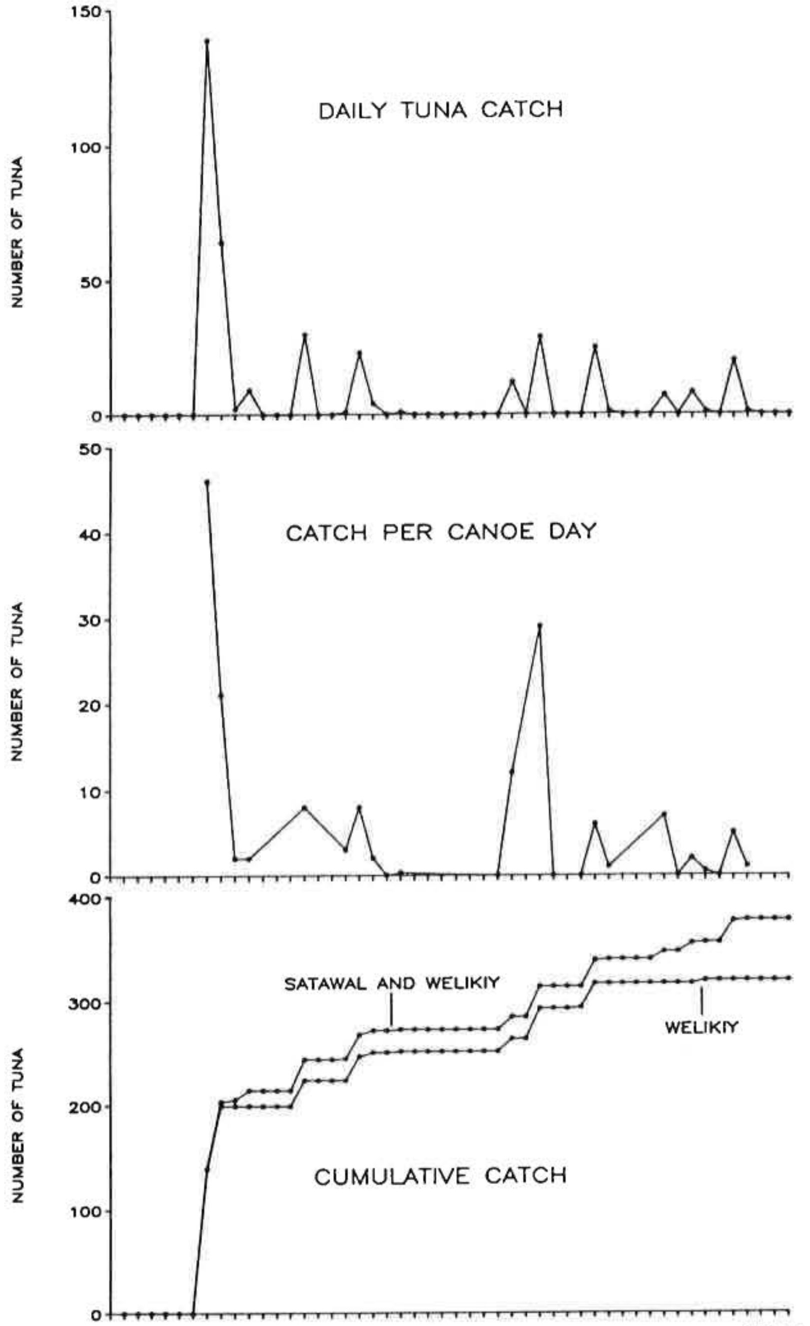


Figure 56: Fish catch data from Satawal and Welikiy fishing grounds (6 Nov 1983-24 Dec 1983), Caroline Islands (after Gillet 1987: 34).

Table 16: Tuna catches by sailing canoes at the Satawal and Welikiy fishing grounds (6 Nov 1983-24 Dec 1983), Caroline Islands (from Gillet 1987: 33).

Sailing canoe name	No. of fishing days	No. of tuna caught	Average no. of tuna caught/ day
Aloha	7	19	2.7
Tiger Line	7	33	4.7
Suntory	5	39	7.8
Rakirh	1	1	1.0
White Horse	7	235	33.6
Fitirep	1	1	1.0
All sailing canoes	28	328	11.7

Several methods of tuna fishing in parts of the Pacific involve specialised equipment to minimise the energy involved in landing the tuna, and to maximise the time available to catch them. Examples of this are the use of the double hulled *tira* canoes once used to catch albacore in the Society Islands (Nordhoff 1930) and the technology used for trolling in many parts of the Pacific. Several lines, each with a lure, may be attached to one rod, so if one breaks or is not attracting biting fish another is immediately available. Furthermore, a feature of the lures used is the lack of barbs on the points. Once hooked, a skilful fisherman can deposit the fish in the canoe and have his line back on the water without the hassle of unhooking the fish.

Although the energy required to land tuna is comparable to other fishing methods, the effort involved in tuna fishing is higher in terms of the time taken to locate tuna. This factor is also highly variable, particularly compared to the more predictable habits of inshore fish. There are also other constraints which limit the viability of tuna fishing. These include weather patterns, and access to canoes and fishing grounds. The strategies considered above also involve communal labour to varying degrees. Canoes used for pelagic fishing offshore usually have a crew of a least three people, while the "canoe of the Pleiades" on Kapingamarangi and the *tira* used in the Societies need larger crews. Fish herding into nets, or the use of leaf sweeps also require community involvement.

Summary

This chapter began with an investigation into the nutritional value of tuna. It was found that tuna is a relatively good source of protein and energy compared to other marine fishes. Other returns provided by tuna fishing are social as opposed to nutritional values, including status and prestige. The reconstruction of tuna size from bones recovered from several archaeological sites demonstrated the variation of sizes present in sites. A review of the effort involved in tuna fishing also highlighted the range of conditions which influence the productivity of this activity. Thus the effort and return provided by tuna fishing in the Pacific needs to be addressed at a local level.

7. Conclusions

This final chapter reviews the findings of this study and discusses what they can tell us about tuna fishing during the prehistoric period in the Pacific region. This study was oriented around several interrelated areas of uncertainty which surround this activity:

(1) the variability of the tuna catch in archaeological sites and the apparent inconsistencies between the archaeological and ethnological evidence for tuna fishing in the Pacific,

(2) explanations for the relatively high proportions of tuna remains in some sites, and

(3) the nature of this fishing activity, whether intentional or opportunistic.

Summary of results

The preferred explanation for the variability of the tuna catch in archaeological sites, derived from the database of accumulated Pacific island fishbone identifications, is the expression of cultural choice by the people who fished. A range of recovery and analytical biases which can affect taxonomic abundance measures do not satisfactorily account for the observed variability.

Fish remains are subject to the same taphonomic effects and site formation processes as other faunal material. Fish bones are particularly vulnerable to the affects of differential preservation, as some skeletal elements are fragile while others are robust (Colley 1990: 215). This varies both within individual fish, and across different taxa. The use of a range of skeletal elements for identification can aid in overcoming such problems. Although the cranial bones of tuna are relatively fragile, the use of the more robust series of bones from the caudal complex can greatly facilitate the identification of this fish family.

The results of any fishbone analysis will be affected by the quality of the reference collection used to make identifications. The collection used for the identifications at the Museum of New Zealand is comprehensive, and contains over 300 fish specimens, including several yellowfin and skipjack, and also a dogtooth tuna. Although identifications are routinely made to the lowest taxonomic level possible, for purposes of quantitative analysis, fish are grouped by family to avoid splitting counts. It is, however, recognised that there are limitations in what can be determined from the resulting data. Many of the fish families found in the Pacific contain a wide range of species, and considerable variation in habitat and behaviour can exist between them. Using the caudal bones it is currently possible to differentiate between the higher tribes (Thunnini and Sardini) and lower tribes (Scombermoroni and Scombrini) in the Scombridae family. The possibility also exists for further intra-family level identifications of this family.

The selection of elements used in identification can affect abundance measures, particularly NISP. Some taxa are identified solely by mouthparts, others by these and special bones. Because such taxa are identified by a wider range of elements, they have a greater opportunity to be identified, and hence are likely to have a greater abundance (Butler 1988: 108). Furthermore, estimates of abundance can also be affected by the number of diagnostic elements present for a particular taxa, depending on the measure used. MNIs were used to reconstruct the fish catch and assess the relative contributions of different taxa to the economic system. MNIs provide a measure which attempts to allow for the differential recovery and identification of elements from fish which contributed to the catch. Issues which affect this measure such as aggregation and sample size have been taken into account. For this study, from the time of excavation all collections were analysed by the same method, providing results which, except for random effects associated with sample size, can be considered comparable.

The possibility that the variation in tuna remains in sites was a result of changes in natural availability was also considered. However, a review of the natural distribution of tuna species commonly found in the Pacific demonstrated a widespread distribution throughout the region. Several members of the Thunnini tribe of the Scombridae family (yellowfin, bigeye, albacore and skipjack) have an oceanic, global distribution. These fish are, however, migratory, and range widely between tropical spawning grounds and subtropical and temperate feeding grounds. The exact nature of these migrations is not yet well understood, but seasonal variation in population density is indicated. There are also several smaller tunas found in association with coastal waters around islands and archipelagos. These are the two Auxis species, the bullet and frigate tunas, and one member of the Euthynnus genus (kawakawa). Several bonitos (tribe Sardini) are also found in coastal Pacific waters, with various local distributions. The dogtooth tuna (*Gymnosarda unicolor*) is a member of this tribe, and is one of the few tuna which is primarily a reef dweller, occurring in mid-water along reef edges. The Spanish mackerels (tribe Scomberomorini) are also predominantly coastal fishes with restricted ranges in the Indo-Pacific. The exception is the wahoo (*Acanthocybium solandri*) which is a frequently solitary, oceanic species. Several members of the Scombrini tribe (mackerels) are also present in the Pacific.

It is argued then, that in some parts of the Pacific throughout prehistory, some groups of people were successfully fishing for tuna, whereas others with equal access were not. This would appear to be a marked contrast with many other sites where fishbone analysis has determined that the majority of fish in the catch were from predominantly inshore areas. Although the tuna fishing expeditions which are described in so many ethnographical accounts are an offshore activity, this activity does not stand alone as the only means of catching tuna. Other strategies have been identified for catching tuna from areas besides the open ocean, including fishing grounds relatively close to shore, lagoons which tuna can enter after prey, and shallow waters occupied during spawning.

A series of archaeological sites in the database at the Archaeozoology Laboratory at Te Papa containing relatively high proportions of tuna were selected for more detailed study, in order to investigate the nature of this phenomenon. The sites were Hane and Te Anapua in the Marquesas Islands, the Fa'ahia-Vaito`otia complex in the Society Islands, and Motupore in Papua New Guinea. The fish catches were reconstructed using MNI and the approach to fishing, particularly towards tuna fishing, was considered. The principal focus of the study was on the evidence obtained from faunal analyses. The dietary contribution made by tuna was assessed, based on the reconstruction of live fish length for the tuna catch. Although an unexpectedly variable range of technology been utilised in the Pacific to catch tuna the relationship between fishing gear in sites and fish bones is a complex one that is considered indicative at best.

The fishing strategies at both Hane and Te Anapua are dominated by line fishing techniques. The majority of fish in both sites are carnivorous and most likely to have either been taken with lures, as in the case of pelagic fish such as tuna, barracuda, long toms and jacks, or baited hooks, for the demersal fish including the Serranidae family, emperors and snappers. Given the nature of the marine environment in the Marquesas this emphasis is perhaps to be expected, since there is a general absence of coral reef areas where browsing fish such as Scaridae are common. The dominance of tuna in both sites is consistent with a specific strategy being practised which targeted these fish.

Two collections of fish bone from Vaito`otia/Fa`ahia in the Society Islands were also considered. When considered together, the fish caught came from a wide variety of marine environments available to people occupying this site. Fish identified ranged from pelagic predators such as tuna and jacks, reef edge families such as rock cods, groupers, and emperors, and also shallow water fish, particularly parrotfish. Yet when the analyses are separated by excavation, major differences between the two collections are apparent. The results of the analysis of fish bone from Sinoto's excavations in the 1970s provided a picture of marine exploitation which led to the people of Fa'ahia being be described as "marine hunters". The reconstruction of the fish catch is dominated by tuna and other pelagic fishes. Also present were other marine taxa, including dolphins and turtles. The results of the analysis of the fishbone from Pigeot's excavations are very different. The reconstructed catch is dominated by shallow water inshore species which form important components of many Pacific island fish catches. Tuna remains are notable in their scarcity. When considered alone, this collection indicates an approach to fishing which concentrates effort on strategies such as netting, spearing and trapping practised in the shallow reef and lagoon waters to which this site has easy access.

By comparison, the results of two analyses of fishbone from the site of Motupore, in Bootless Bay, Papua New Guinea agree in terms of the fishing carried out by the people who occupied the site. The occupation of Motupore spans around 450 years, and the fishing strategies practised during this time appear stable. Tuna make up 8.4% and 3.9% of the catch in the two excavated areas. Although there a number of fish present which are usually taken with hooks, it has been argued that for this site netting was a highly important method, which may have taken over 90% of the catch, including these species (McMurtry 1986). A specific strategy has been identified for taking tuna based on ethnographic evidence. This strategy is aimed at yellowfin tuna which enter the bay to spawn, and are thus susceptible to nets.

Several different strategies for tuna fishing are indicated at Hane, Te Anapua, Vaito`otia-Fa`ahia and Motupore. These include specific strategies using lures or nets, and possibly more generalised methods which include tuna in their range of targeted fish. These strategies all take advantage of aspects of tuna behaviour, such as the tendency, particularly by skipjack and juvenile yellowfin, to form surface schools when feeding, the association of sub-surface schools with hydrological features, and the nature of spawning aggregations. The development of these strategies implies a detailed knowledge of these fish and their habits, as opposed to chance encounters. This type of approach is also apparent in Nordhoff's account of fishing in the Society Islands (1930: 233). He commented that "an accomplished fly fisherman in Europe or America does not carry in his head one-half the store of practical knowledge a bonito fisherman uses everyday".

At both Fa`ahia and Motupore there appears to be differential distribution of tuna remains in the sites. Several possible explanations for the varying composition of catches between the two excavated areas at Fa`ahia were considered, including functional and chronological differences, and differential access to tuna between groups of people at the site. A sociological explanation has also been suggested for the spatial differences at Motupore (Chatan 1992). At this time insufficient is known about these sites as a whole to decide between various alternative explanations.

The importance of tuna at Hane, Te Anapua, Fa`ahia and Motupore was considered from an economic perspective, based on reconstructions of the live size of tuna in sites. It was found that the size of tuna in sites was variable. The small size of tuna at Hane, and the smaller sized fish from Te Anapua and Fa`ahia would not have made a significant quantitative contribution in comparison to other fish caught. Larger fish, particularly from Fa`ahia and Motupore, would have made a significant contribution in terms of food per fish in the catch. From a dietary perspective, tuna contain high levels of protein, and are a good source of energy due in part to the high levels of oil they contain. So even relatively small fish would have provided excellent nutritional returns in comparison to other common Pacific fish species.

The effort involved in tuna fishing is highly variable and dependant on the strategies used. It is also difficult to investigate archaeologically. From ethnohistoric sources, two interrelated aspects of effort were identified for tuna fishing; these were location time, and the energy involved in landing fish. Location time is an important factor in the equation for tuna fishing, particularly in comparison with the kinds of fish available in the reef environment. Strategies aimed at tuna in particular utilise detailed knowledge of fishing grounds and tuna behaviour to minimise the time taken to locate schools. Once located, fishing for tuna can be a highly profitable exercise. Several methods have been developed to minimise the energy required to catch tuna, and to maximise the time available to catch them.

Models for subsistence behaviour that are oriented around the highest return for effort expended do not, however, adequately explain the economic choices people make. A combination of strategies may be used which do not necessarily provide the best returns, but minimise or reduce risk and uncertainty. Furthermore, returns in social terms are not encompassed in this type of approach.

Successful tuna catches provide other returns which are more intangible than nutrition or size. Possible social values associated with tuna and tuna fishing in the Pacific include prestige, marking social status and promoting cultural cohesion and stability. Offshore fishing has had an important role in both determining and identifying social status in many Pacific island communities. This can operate on an individual level, as successful fishermen are respected for their skill and courage, or on a communal level. The control over resources such as tuna and offshore fishing activities can function as indicators of political and religious power within a community. This may be demonstrated in a variety of ways, from the distribution of the catch, to the possession of the equipment required, or control over access to offshore waters.

Offshore fishing occupies a special place in many Pacific island communities which is not adequately encompassed by purely economic motivations. The apparent disparity between the archaeological evidence and ethnographic accounts is a reflection of the way in which offshore fishing is regarded, and is also a function of the differences between the two kinds of information. Offshore fishing for tuna involves excitement and challenges which attracted both local Pacific people and the ethnographers who recorded aspects of their culture. Descriptions of offshore expeditions to catch tuna and the technology involved are describing fishing strategies which were known and practised by informants. What the accounts do not record is the frequency of these expeditions, and their success rate in terms of contribution to the subsistence economy. In contrast, the archaeological evidence from faunal remains documents what made up the fish catch on a regular basis.

Limitations of this research

The research was based around the study of a sample of sites in the Pacific, where consistent methods of analysis enabled comparisons between sites. The use of a range of methods of identification and quantification by researchers working in this region prevented more detailed comparisons with other sites. The development of high quality and more comprehensive reference collections is necessary if accurate identifications of tuna remains are to be made in the future. Larger sample sizes are also required to enable statistically significant results to be obtained.

The method of analysis routinely used at the Museum of New Zealand involves the identification of a limited number of anatomical elements; five paired cranial bones and some special bones diagnostic of particular taxa. The different structures of the tuna assemblages from Fa`ahia highlight possible taphonomic and cultural processes which are obscured by this method, particularly when only cranial anatomy is used. This issue arose during the course of this research, and merits further investigation.

It was hoped to be able to investigate the contribution made by tuna compared with other fish in the catch. The size-frequency reconstructions undertaken to this end should be considered preliminary only. Modern allometric data is yet required for a range of tuna species in the Pacific. The allometric relationship between Scombridae species within families also requires further investigation. At present regression coefficients for bone dimension/size and weight have been established for only one other fish family in the Pacific, Scaridae. Accurate methods for quantifying the live size and weight of fish catches enable a variety of issues to be investigated including economic contributions, the effect of human predation on fish stocks and fishing technology.

Implications for future research

This research has demonstrated that the successful exploitation of tuna was confined to a few sites within the Pacific region, where specialised strategies were probably used to catch the majority of these fish. Although more comprehensive identifications of tuna are possible using a greater number of elements, this is unlikely to alter this pattern of variable relative abundances in sites significantly.

The economic perspective adopted in this study focused on the contribution made by tuna in terms of the overall fish catch. Tuna has been shown to provide a good quality resource; however, the contribution of offshore fishing to the economy is conditioned by a variety of other factors. In order to understand this better, tuna fishing needs to be placed within the wider context of resource use. Trends in the use of offshore resources also have a temporal dimension, which articulates with other cultural and environmental factors. Allen (1992) has linked a decline in angling in the Cook Islands with environmental factors including a decline in pearl shell, and also the intensification of agricultural activities.

Tuna fishing at several of the sites studied here is likely to have been a seasonally defined activity, based on the behaviour of tuna. Therefore the tuna remains in the site were probably deposited over a relatively short period. This is strongly indicated to be the case at Motupore, and probably also for the east Polynesian sites. Tuna are present in the region all year round, however, they are more abundant at particular times of year. Variations in sea and wind conditions affecting fishing technology also influenced tuna fishing in this region. The seasonality of resources in the tropical Pacific has received little attention, although investigations into the seasonal availability of different resources form an important component of subsistence studies in temperate areas such as New Zealand.

Ethnographic accounts from the Pacific often contain references to the seasonality of various resources. For example, tuna fishing in Tahiti in the 19th century was associated with a specific time of year when breadfruit and other fish were plentiful (Handy 1932: 78-79). Seasonality in this sense does not necessarily refer to marked seasons based on significant temperature and weather variations as found in temperate areas, but is often associated with wet/dry times of the year, and the occurrence of particular events, for example the flowering and ripening of plants such as breadfruit. Fluctuations in the availability of different resources may also have implications for settlement patterns.

Fishing for tuna also involves a ranges of social aspects, which need to be considered in interpretations of offshore fishing activities. A range of complex ritual behaviours have been identified in the ethnohistoric record which attempt to offset the risk and uncertainty involved in this activity. Control over offshore fishing activities can act as social markers of religious and/or political control, and can have an important role in the maintenance of social structure. The presence of fish such as tuna in archaeological sites is thus more likely to represent the intersection of both social and economic motivations. Two sites, Motupore and Fa`ahia, considered as part of this research have raised the issue of archaeological investigations of social behaviour associated with specific resources. This has centered around the possible associations of tuna and offshore fish with high status groups, based on differential distribution of tuna remains. In both cases, the distribution of tuna bones varies between areas of the site. Archaeologically these issues are difficult to investigate, but need to be considered if the role of possible status foods such as tuna is to be better understood.

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Appendix 1

This appendix contains a list of selected members of the Scombridae family, their binomial names, common names (boldface indicates the name used in this text), and where appropriate their local names from Satawal (S), Hawaii (H), Kapingamarangi (K), and Tokelau (T).
Sources are as follows: Binomial and common names from Collette and Nauen 1983, Satawal names from Gillet 1987, Hawaiian names from Titcomb 1972, Kapingimarangi names from Leach and Ward 1981, and Tokelau names from Gillet 1985.

Thunnus albacares

yellowfin tuna

S: taku

H: ahi, malailena (yellow fins)

K: dagua

T: kahikahi: small fish, not distinguished from bigeye
kakahi: medium sized fish, not distinguished from bigeye
takuo: large fsih

Thunnus obesus

bigeye tuna

S: taragap

H: ahi, po`onui

T: kahikahi: small fish, not distinguished from bigeye
kakahi: medium sized fish, not distinguished from bigeye
lalavalu: large fish

Thunnus alalunga

albacore

H: ahi, palaha

K: di adu

Katsuwonus pelamis

skipjack tuna, bonito

S: arangap

H: aku

kia`u: immature

ahua: half grown

aku: fullgrown

T: atu

atu: small to medium sized fish

nakono: fish too large to be poled unassisted

tuikaufoe: huge fish, extremely rare, paddle must be used to raise on board canoe.

Euthynnus affinus

kawakawa, little tunny, bonito, mackerel tuna

S: asinoi

H: kawakawa, pohopoho

T: kavalau

Auxis thazard

frigate tuna

S: asinoi

Auxis rochei

bullet tuna

S: asinoi

Gymnosarda unicolor

dogtooth tuna

S: aun

T: tavatava: small fish

valu: large fish

Acanthocybium solandri

wahoo

H: ono

K: di mala

T: pala

Grammatocynus bilineatus

double-lined mackerel

S: paur

K: iga-bou

T: atualo

Appendix 2

The following tables provide the Number of Identified Specimens (NISP) for the each of fish bone collections discussed in Chapter 5.

Table 17: Hane, NISP by fish family

Family	NISP
Anguillidae	2
Muraenidae	2
Leptocephalidae	1
Belonidae	8
Holocentridae	16
Aulostomidae	2
Sphyraenidae	4
Scombridae	537
Carangidae	145
Epinephlidae	158
Lutjanidae	51
Aphareidae	4
Nemipteridae	2
Lethrinidae	34
Mullidae	5
Kyphosidae	9
Scaridae	18
Acanthuridae	8
Diodontidae	52
Balistidae	5
Ostraciidae	3
Elasmobranchii	113
Myliobatiformes	4
Teleostomi	47
Coridae/Labridae	16
Total	**1246**

Table 18: Fa`ahia, Sinoto's excavations, NISP by fish family

Family	NISP
Megalopidae	1
Chanidae	1
Anguillidae	7
Muraenidae	5
Belonidae	25
Hemirhamphidae	2
Exocoedidae	1
Holocentridae	18
Aulostomidae	6
Sphyraenidae	6
Mugilidae	1
Scombridae	514
Carangidae	231
Epinephelidae	142
Lutjanidae	78
Nemipteridae	24
Lethrinidae	102
Mullidae	9
Coridae	5
Scaridae	248
Acanthuridae	13
Scorpaenidae	1
Diodontidae	121
Tetrodontidae	3
Balistidae	66
Ostraciidae	28
Elasmobranchii	21
Teleostomi	2
Total	**1,693**

Table 19: Fa`ahia, Pigeot's excavations, NISP by fish family

Family	NISP
Myliobatidae	1
Anguillidae	1
Muraenidae	8
Exocoedidae	2
Holocentridae	36
Sphyraenidae	3
Mugilidae	29
Scombridae	98
Carangidae	256
Epinephelidae	259
Lutjanidae	137
Nemipteridae	65
Lethrinidae	60
Mullidae	39
Kyphosidae	3
Scaridae	830
Acanthuridae	35
Scorpaenidae	5
Diodontidae	6
Balistidae	65
Ostraciidae	200
Elasmobranchii	59
Myliobatiformes	3
Teleostomi	25
Coridae/Labridae	52
Total	**2,277**

Table 20: Motupore, Groubes's excavations, NISP by fish family

Family	NISP
Dasyatidae	1
Myliobatidae	8
Muraenidae	3
Belonidae	3
Holocentridae	1
Sphyraenidae	6
Scombridae	75
Carangidae	52
Epinephelidae	78
Lutjanidae	119
Nemipteridae	29
Plectorhynchidae	13
Lethrinidae	286
Mullidae	3
Coridae	2
Scaridae	655
Acanthuridae	145
Scorpaenidae	3
Echeneidae	1
Diodontidae	749
Tetrodontidae	83
Balistidae	220
Ostraciidae	38
Elasmobranchii	79
Teleostomi	2
Coridae/Labridae	224
Zeidae	2
Total	**2880**

Appendix 3

The following table provides the estimates of size for common Pacific fish families.

Sources: Munro 1967, Randall *et al.* 1990 and personal observations (Foss Leach pers. comm.).

Table 21: Estinates of fish size for common Pacific fish families.

Family:	Hane (mm)	TeAnapua(mm)	Fa`ahia (mm)	Motupore (mm)
Scombridae	350	500	530	725
Elasmobranchii	1220	1220	1220	1220
Megalopidae	000	000	450	000
Chanidae	000	000	450	000
Anguillidae	1000	000	1000	000
Muraenidae	1000	1000	1000	1000
Leptocephildae	1000	000	000	000
Belonidae	800	800	800	800
Hemirhamphidae	000	000	450	000
Exocoetidae	000	000	250	000
Holocentridae	180	180	180	180
Aulostomidae	500	500	500	000
Sphyraenidae	760	000	760	760
Mugilidae	000	000	355	000
Coryphaenidae	000	000	000	1270
Carangidae	700	700	700	700
Serranidae	600	600	600	600
Lutjanidae	500	500	500	500
Caesiodidae	000	250	000	000
Nemipteridae	500	500	500	500
Lethrinidae	400	400	400	400
Mullidae	300	300	300	300
Kyphosidae	350	000	350	000
Coridae/ Labridae	300	300	300	300
Scaridae	400	400	400	400
Acanthuridae	300	300	300	300
Scorpaenidae	000	000	300	000
Diodontidae	300	300	300	300
Balistidae	300	300	300	300
Aluteridae	000	300	000	000
Ostraciidae	200	200	200	000
Myliobatiformes	1220	000	1220	1200
Teleostomi	400	400	400	400
Istiophoridae/ Xip	2200	000	000	2200
Aphareidae	350	000	000	000
Platacidae	000	450	000	450
Tetrodontidae	000	300	300	300
Plectorynchidae	000	000	000	400
Zeidae	000	000	000	400