In the land of the Ichthyophagi: Modelling fish exploitation in the Arabian Gulf and Gulf of Oman from the 5th millennium BC to the Late Islamic period

2 volumes

Volume 1: Text

Mark J. Beech

DPhil

University of York

Department of Archaeology and Department of Biology
(Environmental Archaeology Unit)

January 2001

ABSTRACT

This study addresses a number of key issues relating to the coastal archaeology of southeast Arabia. Namely, what role did chronological developments play in the characterisation of fisheries exploitation patterns? What was the influence of the environment in this region? Are there any modern fisheries or archaeological data to support the notion that the inhabitants of this region practised a transhumant and seasonally based existence, occupying the coast or interior during particular seasons? Is it possible to identify traces of fish processing, dried fish or possible evidence for fish storage and trade in the archaeological record of the area?

The primary data forming the basis for this study are 23 archaeological fish bone assemblages from sites located in the Arabian Gulf and Gulf of Oman, with a particular focus on the southern Gulf region and the present day coastline of the United Arab Emirates. The chronological focus of this study is from the 5th millennium BC to the Late Islamic period.

Various techniques were used to model regional variability in archaeological fish bone assemblages. These included standard zooarchaeological quantification techniques as well as percentage sample presence, measures of ecological diversity (Shannon-Wiener and Simpson diversity indices), cluster analysis and Renkonen's percentage similarity. The study highlighted three main types of assemblages, sites with shallow water and reef species, sites with numerous remains of Chondrichthyes, and sites with higher numbers of pelagic fish, particularly tuna and mackerel. Sites clustered according to similar regions or environments rather than according to any chronological principle.

A pilot study on Lethrinid otoliths questioned some of the currently adopted models relating to transhumance and seasonality. It is suggested that further studies should be carried out in conjunction with other researchers working in the region to critically evaluate these pilot results.

LIST OF CONTENTS

VOLUME 1 – TEXT

Page no.

Chapter 4. The chronological development of fisheries in the Arabian Gulf and Gulf of Oman: Past studies 86

VOLUME 2 – FIGURES, TABLES AND APPENDICES

List of Figures Page no.

List of Tables — Page no.

LIST OF APPENDICES **Page no.**

ACKNOWLEDGEMENTS

This research was financially supported by a University of York research studentship based within both the Departments of Archaeology and Biology (Environmental Archaeology Unit). Additional financial contributions came from the following organisations: the Abu Dhabi Islands Archaeological Survey project (ADIAS), the British Council (Abu Dhabi office) and the Environmental Research and Wildlife Development Agency (ERWDA), Abu Dhabi, United Arab Emirates.

The Abu Dhabi Islands Archaeological Survey project (ADIAS), as well as the Graduate Studies Board of both the Departments of Archaeology and Biology, generously provided grants enabling my attendance and participation at a number of conferences during the course of this research. These were as follows: the 4th International ICAZ Symposium on the archaeozoology of southwestern Asia and adjacent areas (ASWA), held in Paris, France (29 June - 3 July 1998); the 8th International Council of Archaeozoology (ICAZ) conference, held at the University of Victoria, British Columbia, Canada (23rd – 30th August 1998); the 10th meeting of the ICAZ Fish Remains Working Group, held at Hunter College, New York City, U.S.A (24th September - October 2nd 1999); the 1st International Symposium and Workshop on Arid Zone Environments: Research and Management Options for Protected Areas, held in Abu Dhabi, United Arab Emirates (January 23-25th 2000); and the 2nd Arab Conference and Exhibition on Environmental Biotechnology - Coastal Habitats (Arab Envirotec 2), held in Abu Dhabi , United Arab Emirates (April 8-11, 2000).

The Anglo-Omani Society and Department of Western Asiatic Antiquities at the British Museum provided a grant to support my attendance and participation at the Historic Oman: Cultures, Contacts and Environment Conference (17-19 July 2000).

The Abu Dhabi Islands Archaeological Survey project (ADIAS) and the Graduate Studies Board of the Department of Archaeology, University of York, also provided a travel grant enabling a week long research visit to Dr. Melinda Zeder, Archaeobiology Laboratory, National Museum of Natural History, Smithsonian Institution, Washington D.C., U.S.A. (October 3rd - 9th 1999). This enabled the study of the fish bones from Dosariyah, Saudi Arabia.

Special thanks go to my wife, Maria, without whose unfailing support I would have never been able to carry out this research. She had to endure my long absences abroad carrying out fieldwork and was a constant source of encouragement to me during the past four years. I would like to also thank my family, and in particular my parents (Helen and Jonathan Beech) and my sister and brother-in-law (Sarah and Jonathan Lee), for their general support and financial assistance.

I am grateful to my two supervisors for their advice and encouragement, Don Brothwell (from the Department of Archaeology) and Keith Dobney (who at that time was at the Environmental Archaeology Unit in the Department of Biology, and is now based in the Department of Archaeology at the University of Durham). The additional members of my thesis assessment panel (TAP) committee provided useful feedback during the course of my research. These were as follows: Andrew Jones (of the York Archaeological Trust and Department of Archaeology, University of Bradford) and Rupert Ormond (then of the Department of Biology at York, but now based at the Marine Research Station at Millport, University of Glasgow). Rupert's place was subsequently taken by Callum Roberts from the Department of the Environment at the University of York.

James Barrett (Department of Archaeology, University of York), Carl Phillips and Chris Mosseri-Marlio (both formerly of the Institute of Archaeology, London) kindly read earlier drafts of my thesis and made constructive comments.

Harold Mytum, head of the Department of Archaeology, kindly provided me with generous laboratory facilities, enabling me to squeeze all my boxes of fish bones and extensive reference material into the Mary Cudworth Studio Laboratory within King's Manor. I would like to thank in addition all my friends in the Department of Archaeology for their unfailing support, advice and encouragement, which included numerous beers in The York Arms and other venues around York. These include: Pat Excell, Stephen Rowland, Charlie Stokes and in particular Mark Whyman, my staunch Friday night drinking companion.

I would like to thank Dr. Peter Hogarth, from the Department of Biology at the University of York, for identifying the crab remains from the archaeological sites analysed in this study. Dr. Mohammed Salem (formerly of the same department, now a research officer at the Ras Mohammed Marine Reserve in Egypt) assisted with the seasonality pilot study, by helping to section the modern and archaeological otoliths from Sir Bani Yas and Umm al-Qaiwain.

Thanks also go to all my friends in the Biology department who at one time or another during the past three and a bit years have provided assistance or helped with various queries relating to my research. These include (in alphabetical order): Liz Ashton, Fiona Gell, Peter Hogarth, Jerry Kemp, James Merryweather, Rupert Ormond, and Nicky Peete. Callum Roberts and Julie

Hawkins from the Environment Department also provided a number of difficult to find references and helpful advice.

Special thanks go to all my friends and colleagues with whom I have worked regularly in the United Arab Emirates on fieldwork each year since 1994. These include the members and associates of the Abu Dhabi Islands Archaeological Survey (ADIAS) team (in alphabetical order): Simon Aspinall (Abu Dhabi), Soren Blau (Centre for Pacific Studies, Canberra, Australia), Beatrice de Cardi OBE (London), Rob Carter (Wiltshire), Jakub ('chaz') Czastka (Sydney, Australia), Arleen Edwards (Abu Dhabi), Joe and Katrin Elders (Hitchin), Salvatore Garfi (Wales), Peter Hellyer (ADIAS executive director, Abu Dhabi), Nadia Iacono (Sydney, Australia), Geoffrey King (ADIAS academic director, School of Oriental and African Studies, University of London), Caroline Lehmann (Florida, USA), John Martin (Carlisle) and Alan Pipe (Museum of London). I would also like to thank the other archaeological teams with whom I have had the pleasure of working during the course of this research. These include (in alphabetical order): Harriet Crawford (Institute of Archaeology, University College, London), Derek Kennet (Department of Archaeology, University of Durham), Carl Phillips (formerly of the Institute of Archaeology, University College, London), Tatsuo and Hanae Sasaki (University of Kanazawa, Japan), Hans-Peter and Margarethe Uerpmann (University of Tuebingen, Germany), and Christian and Imke Velde (National Museum of Ras al-Khaimah, United Arab Emirates).

Other fellow zooarchaeologists who provided useful advice or information included: Bill Belcher (Hawaii), Caroline Cartwright (Department of Scientific Research, British Museum), Jean Desse and Nathalie Desse-Berset (CNRS Valbonne, France), Foss Leach (Museum of New Zealand), Arturo Morales and Eufrasia Rosello (Autonoma University, Madrid), Chris Mosseri-Marlio (Tunbridge Wells), Sophia Perdikaris (Brooklyn College, University of New York), Hans-Peter and Margarethe Uerpmann (University of Tuebingen, Germany), Wim van Neer (Royal Africa Museum, Belgium), and Melinda Zeder (National Museum of Natural History, Smithsonian Institution).

Author's declaration

A brief note on the animal bones from the early excavation seasons at Kush has already been published in the journal *Arabian Archaeology and Epigraphy* (Beech and Pipe 1997).

An oral presentation of the Sasanian/Early Islamic fish fauna from Sir Bani Yas was given to the day seminar on "Sasanian Agriculture and Technology - New Directions of Research", organised by Dr. St. John Simpson, held in the Department of Western Asiatic Antiquities, British Museum, on the 15th June 1998.

Brief comments on the vertebrate fauna from early Islamic Jazirat al-Hulaylah and Islamic Julfar have been published in the *Bulletin of Archaeology of the University of Kanazawa* in Japan (Beech 1998).

An oral presentation of some of the preliminary results of the analysis of the Dalma and northern Emirates fish assemblages was given to the 8th International Council of Archaeozoology (ICAZ) conference, held at the University of Victoria, British Columbia, Canada, between the 23rd - 30th August 1998. This was presented within the session entitled: "Current Topics in South Asian and Gulf Archaeozoology", chaired by William Belcher.

A note on the new species of triggerfish recorded within the Arabian Gulf was published within the journal *Tribulus* (Beech 1999).

Preliminary results of the 1998 excavations of the 'Ubaid settlement at Dalma site DA11 have been published in the *Bulletin of the Society of Arabian Studies* (Beech and Elders 1999). An oral presentation of the results of these excavations was presented at the Seminar for Arabian Studies Seminar, Institute of Archaeology, University College, London (5th-17th July 1999). This will be published in the forthcoming volume of the *Proceedings of the Seminar for Arabian Studies*.

The vertebrate fauna from UNAR2, the Umm an-Nar tomb in Ras al-Khaimah has already been published in *Arabian Archaeology and Epigraphy* (Blau and Beech 1999).

An oral presentation of the results of the analysis of the emperor otoliths from Umm al-Qaiwain was presented at the 10th meeting of the ICAZ Fish Remains Working Group, held at Hunter College, New York City, U.S.A (24th September - October 2nd 1999).

An oral presentation discussing the environmental archaeological remains found at coastal sites in the Emirates was co-presented with Peter Hellyer at the 1st International Symposium and Workshop on Arid Zone Environments: Research and Management Options for Protected Areas. This was organised by the Environmental Research and Wildlife Development Agency (ERWDA), Abu Dhabi, United Arab Emirates (January 23-25th 2000). This will be published by ERWDA in a forthcoming monograph.

An overall discussion of archaeological fish remains in the Emirates was presented at the 2nd Arab Conference and Exhibition on Environmental Biotechnology - The Coastal Habitats (Arab Envirotec 2), held in Abu Dhabi , United Arab Emirates (April 8-11, 2000). This will be published in a forthcoming volume by the Commission for Environmental Research, Emirates Heritage Club, Al-Samaliyah, United Arab Emirates.

An oral presentation of the comparative analysis of 5-4th millennium BC fish assemblages was presented at the Historic Oman: Cultures, Contacts, Environment Conference. This was sponsored by the Anglo-Omani Society and organised at The British Museum by the Department of Western Asiatic Antiquities (17-19 July 2000). This will eventually be published in a forthcoming edition of the *Journal of Oman Studies.*

A preliminary report on the 'Ubaid fish fauna from Dalma site DA11 (Beech 2000) has already been published in the *Proceedings of the 4th International Symposium on the archaeozoology of southwestern Asia and adjacent areas* (Mashkour et al. 2000). This paper was initially presented at the symposium which was held in Paris, France, between the 29th June - 3rd July 1998.

CHAPTER 1

INTRODUCTION

Fishing forms an important activity in many societies throughout the world today and played a significant role in the life and subsistence of many prehistoric societies (Acheson 1981; Yesner 1980). Past archaeological research on fishing has often tended to concentrate on particular sites or chronological periods. This study aims to adopt an inter-disciplinary approach to model regional interactions between coastal communities and their environment. The geographical framework for this study is the Arabian Gulf/Gulf of Oman, with a particular focus on the southern Gulf region and present day coastline of the United Arab Emirates. The environmental and archaeological background to the region will be first of all considered. Modern fisheries data, as well as ethnographic data relating to traditional fisheries will be discussed. An evaluation is carried out of all the archaeological evidence for the adoption of particular fisheries technology. The principal data forming the basis for this study are 23 archaeological fish bone assemblages from sites located throughout the Arabian Gulf/Gulf of Oman. The chronological focus of this study is from the 5th millennium BC to the Late Islamic period. In order to comprehend the regional variation in fisheries, sites were selected on the basis that they represented a variety of site types in different environments scattered throughout the region. The overall aim of this research will be to consider the interactions between the goals of these coastal societies, their fishing strategies and environment (Figure 1).

Comparatively little zooarchaeological work has been carried out in this region until recent years. This is largely because our knowledge of the archaeology of this area has only recently been enhanced due to intensive archaeological activity during the course of the past decade. Recent archaeological excavations carried out by a number of international archaeological teams have provided important new knowledge concerning the development of the chronology and history of settlement. Although we now have some idea of overall chronological developments in this region much work still remains to be done. In particular, we still have a very scanty knowledge concerning the palaeoenvironment of the coastal waters of the Arabian Gulf. We also know comparatively little about the palaeoeconomy and the relative importance of different food resources through the prehistoric to protohistoric period. This is despite the fact that marine resources, and in particular fish, have clearly played a significant role for thousands of years in this region. This study aims to go some way towards addressing some of the key questions of relevance to the archaeology of south-east Arabia.

1.1 Research objectives

These specific research questions are:

- What role did chronological developments play in the characterisation of fisheries exploitation patterns?
- What is the influence of space and environment in this region?
- Are there any modern fisheries or archaeological data to support the notion that the inhabitants of this region practised a transhumant and seasonally based existence, occupying the coast or interior during particular seasons?
- Is it possible to identify traces of fish processing, dried fish or possible evidence for fish storage and trade in the archaeological record of the area?

Chapter 2 provides an introduction to the environmental and archaeological background to the study region. In Chapter 3 the modern and traditional fisheries of the Arabian Gulf and Gulf of Oman are examined. Chronological factors will be discussed in Chapter 4, based on already published studies of zooarchaeological, archaeological and historical data. New zooarchaeological data in the form of fish bone assemblages from 23 sites located in the Arabian Gulf and Gulf of Oman are presented in Chapter 5. The influence of space and environment will be evaluated in Chapter 6. The question of seasonality and traditionally adopted transhumance models will be examined in Chapter 7. Chapter 8 examines the evidence for fish processing, dried fish and possible evidence for fish storage and trade in the archaeological record of the region.

This research will provide for the first time a detailed insight into the status of past fisheries resources in the region as well as an insight into the fishing strategies utilised by the early coastal inhabitants of the Gulf during the course of the past 7000 years. A special focus will be on the use of biometrical techniques to enable size reconstruction of economically important fish groups. By collecting data from a number of sites in the region using a reliable and standardised system of recording., for the first time it will be possible to enhance our narrative of past human interactions with the coastal marine environments of the Gulf.

1.2. The study of archaeological fish bones: a brief methodological review

The study of fish remains from archaeological sites is now an integral part of environmental archaeology (Casteel 1976; Colley 1990; Ryder 1969; Shackley 1981: 181-191; Wheeler and Jones 1989). During the past twenty years the number of specialists studying fish remains has expanded dramatically, leading to the formation in 1981 of what was to become an international group of affiliated workers, the I.C.A.Z. (International Council of Archaeozoology) Fish Remains Working Group (Morales 1996). Since the publication of "Fish Remains in Archaeology" (Casteel 1976) there have been a considerable number of publications concerning archaeological fish remains, many arising from conferences organised by the aforementioned research group (e.g. Desse-Berset 1984; Heinrich 1994; Morales et al. 1996; Van Neer 1994). Past work has concentrated on several key issues including: the sampling and retrieval of fish remains (e.g. Clason and Prummel 1977; Jones 1982; Payne 1975), the construction of osteological comparative collections (e.g. Clason 1983; Leach 1986; Wheeler and Jones 1989: 177-185) and taphonomic problems relating to the preservation of fish bones on archaeological sites. Factors such as burning or cooking (e.g. Richter 1986; Nicholson 1996), chewing and ingestion (e.g. Jones 1983,1986), weathering (e.g. Bullock and Jones 1987), trampling (e.g. Jones 1987) and scavenging (e.g. Walters 1984) have been considered. Various quantification techniques have also been discussed (e.g. Barrett 1994; Grayson 1979,1984; Klein and Cruz-Uribe 1984; Ringrose 1993). More recent work has focussed on osteometric approaches to the study of fish bones (e.g. Chaix and Desse 1994; Desse and Desse-Berset 1996a,b,c; Jonsson 1994; Zohar et al. 1994,1997) as well as the use of ethnographic analogies for modelling ancient fishing strategies (e.g. Belcher 1994; Desse-Berset 1994; Juan-Muns 1994). There has also been a move in more recent years towards regional synthesis (e.g. Leach and Boocock 1993; Leach 1999; Wing 1994, 1998; Wing and Scudder 1983), as well as to develop an understanding of broader questions such as seasonality (e.g. Cartwright 1994, 1998) and trade (e.g. Barrett 1995, 1997; Perdikaris 1998). This present study is grounded largely and takes its inspiration from these latter concerns.

The majority of past zooarchaeological research on fish bones detailed above has concentrated on the study of material from archaeological sites located within Europe, the Near East, the Americas or Oceania (cf. bibliographies in Casteel 1976; Wheeler and Jones 1989; and the various ICAZ meeting publications). With only few exceptions very little work has been carried out on archaeological fish remains from south-west Asia, and in particular from the Arabian Gulf region. Those publications that do exist are often preliminary in nature, do not present details of the methods utilised to study the assemblages and occasionally include some questionable identifications. This study aims to initiate a closure of this gap in our knowledge by bringing together a regional picture of human interactions with the marine environment in the Gulf. This will hopefully form a baseline to provoke further research in the region.

1.3. "In the land of the ichthyophagi"

Various factors make the Arabian Gulf region a distinct entity. Its peripheral location means that it has a lower diversity of marine biota than elsewhere in the Indian Ocean, partly as a result of its separation and then comparatively recent re-connection to the Indian Ocean. This means that the diversity of species is far less than in some of the surrounding waters of the Western Indian Ocean region, e.g. at least 1000 species of fishes are known from the Red Sea (Dor 1984) and at least 930 from the coastal waters of Oman (Randall 1995). Within the Arabian Gulf there are somewhere between 200-500 species (Al-Baharna 1986; Blegvad 1944; Carpenter et al. 1997; Downing 1985, 1987; Kuronuma and Abe 1972, 1986; Relyea 1981; Sivasubramaniam and Ibrahim 1982; Smith and Saleh 1987; Smith et al 1987; White and Barwani 1971; see chapter 3 for a further discussion of these sources).

Habitats within the region range from estuary, lagoon, mangrove, rocky and sandy coastlines to deeper offshore waters (Basson et al. 1977). Early fishing communities would have had the opportunity and technology to exploit all of these. Does the occurrence of particular fishes in the zooarchaeological record provide an insight into the significance of which ecological zones were favoured through time?

The question of seasonality is a key issue not only for the ancient populations of the Gulf. It has also preoccupied much of the more recent populations inhabiting the region up until the more recent oil-rich era. The Bedouin of south-east Arabia traditionally moved around between inland oases and the coast on a regular annual cycle (Cordes and Scholz 1980, Lancaster 1988, Wilkinson 1977). Do modern fisheries data provide information about the occurrence of particular resources at certain times of year or in particular locations? Can the zooarchaeological data shed any light on seasonal subsistence patterns in the past?

An understanding of the development of fisheries in the region cannot proceed without a consideration of the role of changing technology. Although determining the functional aspects of prehistoric material culture data is limited by the types of surviving evidence, it can still provide us with a valuable insight into the past. Are there any changes in the types of fishing equipment in the archaeological record suggesting shifting exploitation patterns?

The Gulf, as has been pointed out earlier, has always been an important corridor for trade with its surrounding regions. Trade was clearly of some importance even from the earliest periods. During the 5th - 4th millennium BC a number of sites throughout the western seaboard of the Gulf have sherds of 'Ubaid pottery denoting contacts with southern Mesopotamia. The presence of imported ceramics, soft stone vessels, chert weights and stamp and cylinder seals has already been noted for the 3rd-2nd millennium BC, suggesting contacts with the civilizations of Mesopotamia, Persia and the Indus. The copper trade clearly became a significant factor from the 3rd millennium BC onwards. Archaeological finds in later periods similarly demonstrate far reaching contacts with distant lands. What sort of products would have been exchanged or bartered in return for these goods? Is it possible that fish products may have played a significant role? Can we identify traces of these products in the archaeological record? Does the surviving evidence suggest any form of intensification in trade during particular time periods?

1.4. Summary

Following the introduction, this study is organised into the following chapters:

Chapter 2 covers the environmental and archaeological background to the study region. After defining the geographical boundaries and characteristics of the study area, climatic data is examined as well as regional variations in water temperature and salinity. A discussion of historical climate change is followed by a summary of our present state of knowledge concerning sea level changes in the Gulf. The latter half of this chapter discusses the previous archaeological and palaeoeconomic research which has been carried out in the region.

Chapter 3 examines the modern fisheries of the Arabian Gulf and Gulf of Oman by a review of the published evidence. This includes reference to studies concerning the number of fish present within the Gulf, their habitat preferences, and some of the modern, as well as traditional techniques used to capture fish within the region. Additional field data collected by the author from "grey literature" as well as from municipal fisheries offices in the UAE are included here.

Chapter 4 considers the chronological development of fisheries in the Arabian Gulf and Gulf of Oman, based on past studies. The results of previous zooarchaeological research are summarised and discussed. Archaeological evidence for the adoption of particular fishing technology is then reviewed. This includes a discussion of all archaeological finds relating to fishing equipment, including net sinkers, fish hooks and traps. Reference is also made to documentary sources relating to the development of fisheries in the region.

Chapter 5 firstly outlines the methods utilised to analyse fish bone assemblages from 23 archaeological sites located in the Arabian Gulf and Gulf of Oman, then presents the results of this study. Each of the archaeological sites is described in turn. Various quantitative methods are used to describe the material. Information is provided concerning the fish taxa, elements, and size of taxa represented. The intra-site distribution of material is commented upon if it is significant.

Chapter 6 examines the influence of space and environment on fisheries in the Arabian Gulf and Gulf of Oman by comparing the zooarchaeological vs. modern fisheries data. The likely habitats exploited by early fishing communities are discussed.

Chapter 7 considers the question of seasonality and traditionally accepted regional transhumance models. Possible evidence for seasonality is evaluated, and the problems involved with the precise determination and identification of seasonal resource procurement are reviewed.

Chapter 8 examines the evidence for fish processing, dried fish and possible evidence for fish storage and trade in the archaeological record of the region.

Chapter 9 is the concluding chapter and summarises the overall results of this study. Future research goals are suggested, and a concluding statement is provided.

Appendix 1 contains information concerning the taxonomy, size and habitat information of the fish taxa mentioned in this study (following Randall 1995; Carpenter et, al 1997).

Appendix 2 provides details of the preparation techniques used in the creation of the osteological comparative collection of Arabian Gulf fishes.

Appendix 3 presents a complete catalogue of the osteological comparative collection of Arabian Gulf fishes, made during the course of this study.

Appendix 4 provides a list of definitions and abbreviations used in the tables, including both (a) species codes, and (b) anatomical element codes.

Appendix 5 contains the quantification of fish remains from each of the studied archaeological sites by context.

Appendix 6 provides a more detailed description of some of the archaeological sites and information concerning their stratigraphy.

Appendix 7 contains a summary of the fragmentation and preservation data for each of the archaeological sites.

Appendix 8 presents a summary of fish assemblage NISP data from all sites in the Arabian Gulf and Gulf of Oman.

CHAPTER 2

ENVIRONMENTAL AND ARCHAEOLOGICAL BACKGROUND

The aim of this chapter is to develop an understanding of the physical environment of the study region. This is vital to our understanding of the interaction of human populations with the coastal zone. The chapter is divided into two main parts. Firstly, the environmental background to the study region is considered (section 2.1). After defining the study region (section 2.1.1), there is a discussion of the physical features which form the Arabian Gulf and Gulf of Oman (section 2.1.2). Climatic data is examined as well as regional variations in water temperature and salinity (section 2.1.3.). A discussion of historical climate change (section 2.1.4.) is followed by a summary of our present state of knowledge concerning sea level changes in the Gulf (2.1.5.). The second half of this chapter discusses the historical and archaeological background to the study region (section 2.2). Early documentary evidence is assessed (section 2.2.1), including information provided by travellers, traders and explorers in the region (section 2.2.2), as well as by Portugese and British colonial observers (section 2.2.3). Finally, there is a consideration of previous archaeological and palaeoeconomic research which has been carried out in the region (section 2.2.4).

2.1. Environmental background to study region

2.1.1. Definition of area

The area which this study deals with is principally the Arabian Gulf (sometimes described as the Persian Gulf), and it will be referred to here using the generic term "The Gulf" following Bulloch (1984: 1) and Peck (1986: 1). A particular focus will be on the southern part of the Gulf, namely the coastline of the United Arab Emirates, henceforth referred to as "the UAE". The study area also includes the coastline of the UAE which extends outside the Gulf along the Batinah coast/Gulf of Oman.

2.1.2. The Gulf – physical features

The Gulf is about 1000 km by 200-300 km and has an average depth of about 35m, dipping downwards in its northern half to a trough of about 60m maximum depth which runs roughly parallel along the Iranian coast, deepening to about 100m near the Strait of Hormuz (Figure 2). It can broadly be divided into three distinctive regions: the northern Arabian

Gulf basin, the Interior Platform (the modern day Eastern Province of Saudi Arabia, Bahrain and Qatar), and the shallow southern third of the Gulf.

At the northern end of the Gulf the vast deltaic plain of the Euphrates, Tigris and Karun rivers forms an area of swamps, sandbars, spits and islands with fluctuating boundaries. The area of Thesiger's "Marsh Arabs" is today under threat from drainage and reclamation schemes, as well as damming of the waters upstream. The Gulf lies between the Arabian and Iranian plates, and there is a strong contrast between the sheer eastern coast and the flat, low western coast. The Arabian western coast is generally low, flat and sandy. Beach sands may be cemented into beach rock. Often a sandbar overtopped by dunes isolates large lagoons flooded in winter but dry and covered by salt or gypsum for the rest of the year. Extensive algal and intertidal flats occur south of the Bahrain archipelago. The coast of the United Arab Emirates is characterized by a number of broad, sandy flats and lagoons and edged with barrier and fringing reefs. The eastern coast is a region of extensive continental sedimentation. It is flat and low as far as Bushehr, then rocky and cliffed. In front of Ras Musandam the coast forms a large recess at the Strait of Hormuz, with two main islands, Queshm and Hormuz. Along the north shore, cliffs and deltaic plains alternate.

The bottom topography is mostly flat and featureless and tends to be dominated by soft sediments (Figure 3). Much of the southern Gulf is characterised by sandy bottoms, whilst the northern and eastern areas are dominated by muddy, or mud and sand, bottoms. Low sandy islands with fringing and patch reefs extend from Kuwait Bay southwards along the Saudi Arabian coast. The southern waters of the Gulf, between Qatar and the UAE, are very shallow. A series of islands off the coast of the western UAE have further fringing and patch reefs (Figure 4), which restrict the movement of water in this area leading to high salinity levels. Water entering the Gulf tends to flow parallel to the eastern (Iranian) coast in deeper waters before eventually circulating in an anti-clockwise fashion eastwards along the UAE coastline (Figure 5).

The basic features of the Gulf can be divided into a northern and southern or eastern regime. The characteristics of these have been described in some detail by Johns et al. (2000). The northern regime is dominated by wind forcing to the south along the axis of the Gulf and the riverine input at the Gulf's head. There is a downwelling on the western coast and upwelling on the coast of Iran, and evidence for a southeastward flowing coastal current along both the northern and southern coasts (Reynolds, 1993). The flow along the Kuwait and Saudi coast is augmented by the freshwater input from the north which forms a riverine plume. The river inflows are approximately split between the flow out of the Shalat Ariabi (Tigris and Euphrates) and rivers flowing out of the highland of Iran (the Hendijan, Hilleh, and Mand). The present day flow of the Shalat Ariabi is much smaller than it once was because of massive dam projects in Turkey. It is not clear what changes this decline in freshwater input has made. The central part of the northern Gulf appears to be fairly stagnant (Reynolds, 1993). The southern end of this regime corresponds roughly to the longitude of Qatar and Bahrain, although the termination of the northern circulation is poorly understood. The flow along the Iran coast seems to continue into the southeastern basin as a tightly trapped coastal current extending perhaps as far as the Strait of Hormuz. This flow becomes very complex in proximity to the island of Jazareh in the northern portion of the Strait (Johns et al. 2000).

The Gulf is generally a very shallow sea. As a result of these shallow waters the Gulf has a strong sedimentary province and favourable environment for the production of biogenic carbonates (Purser 1973; Siebold 1973). In the UAE this has led to the formation of coastal "sabkha" or low-lying saline flats subject to periodic innundation. This dominates the coastline west of Abu Dhabi island, where the sabkha may extend more than 15km inland (Feulner 1996). The formation of this sabkha has led to the Abu Dhabi coastline prograding (advancing seaward) by about 25km during the past 5000 years (Feulner 1996: 30). Offshore underlying salt domes have forced upward numerous islands and banks of hard substrata colonised by corals (e.g. Dalma and Sir Bani Yas islands), most of these islands having important fringing reefs. This has led to the creation of a barrier complex of islands and shallows. Much of the shoreline consists of gently sloping beaches with a gradual blending of marine-terrestrial conditions sometimes extending over a number of kilometres. Much of the UAE coastline is characterised by these shallow waters and barrier islands, although deeper waters with more extensive coral reefs can be found along the northern coast, nearer to Musandam and the Straits of Hormuz.

2.1.3. Climate, Temperature and Salinity

The study area is a subtropical zone lying almost entirely between 30 and 24 degrees N. Due to the surrounding arid land masses, the summers are hotter and winters colder than in most other subtropical zones. Air temperatures can reach extremes of around 10 degrees C in winter and 50 degrees C and above in summer. Water temperatures can fluctuate between as low as 4 degrees C in the shallow waters off Qatar and around 7 degrees C off Kuwait during the winter (Shephard et al. 1992). Offshore surface water temperatures tend to vary between about 18 and 33 degrees C. Many of the organisms in the Gulf probably live at the limits of their physiological tolerance.

In the southern Arabian Gulf the climate of the UAE is today classified as hyper-arid. Within the country however there are different bio-climatic zones. North-eastern areas have higher mean precipitation rates, and lower temperatures, in comparison with the southern and the western region (Boer 1997). Despite the commonly held belief that the Gulf is always hot and dry, there are in fact two distinct seasons: summer and winter. Summer temperatures, between May to September, are remarkably hot, temperatures reaching up to 45°C. The average humidity levels attain anything between 37 to 63%. Winter temperatures, between December and February, are much cooler being between 10-30°C on average (Morbin 1995: 138; Stevens 1975: 150; Stanger 1994: 89).

The aridity of this region along with great seasonal fluctuations of air and water temperatures also plays a part in the environmental makeup of the region. Seasonal wind variations are also significant throughout the Gulf. In the winter time northerly "Shimal" winds blow over the shallow waters causing its temperature to fall to almost temperate values. This can occasionally cause massive mortalities to the marine biota (Sheppard et al. 1992: 37).

Salinities generally range from about 38-40 o/oo, increasing to more than 60 o/oo in areas such as the Gulf of Salwa, but fall to around 37o/oo in the Gulf of Oman. Tides in the Kuwait region range up to 3.5-4.0 meters, whereas south of Al Kobar, on the Saudi coast, they are less than 1 metre.

A detailed study of the regional variation in temperature and salinity in the southern Gulf has been conducted by Ali and Cherian (1983). They sampled four stations along the coastline of the UAE (Figure 6), three sampling locations being inside the Gulf (Abu Dhabi, Umm al-Qaiwain and Ras al-Khaimah) and one being on the Gulf of Oman coast (Khor Kalba). The results of their collation of data relating to water temperature and salinity for bottom layers are summarised in Figures 7-8. Water temperatures within the Gulf rise much higher during the summer months, and attain lower temperatures during the winter months, than on the Gulf of Oman coastline (Khor Kalba, station 4A). There is also a marked difference in salinity levels between the different stations (Figure 8). A clear gradation can be seen according to the location of the site. The Gulf of Oman has much lower salinity levels than within the Gulf itself. The difference between the sample stations based in the northern Emirates (Umm al-Qaiwain and Ras al-Khaimah) with the station sampled in Abu Dhabi waters is also clear. Environmental conditions clearly appear to become more severe as one heads westwards along the Emirates coastline towards western Abu Dhabi waters

2.1.4. Reconstructing the ancient climate of SE Arabia

The study of the history of climate change is an area where many of the researchers working in the region seem to struggle to come to any sort of consensus. Despite the brash certainty of some authors (e.g. Dayton 1975: 33; Rice 1994: 75-6), a closer examination of the published literature shows that a uniform picture is far from clear. It seems likely that the contrasting opinions result from the fact that different types of evidence are used by various authors, and the differences may therefore partly represent the limitations of particular types of evidence (Potts 1990a: 20). This climatic evidence is summarised in Table 1.

The general consensus appears to be that around 9000 BP (c. 7000 BC) the Gulf experienced a relatively wet (humid) period. This lasted until around 5-6000 BP (c. 3-4000 BC) when conditions deteriorated to the present hyper-arid conditions. Most people seem to accept the notion that climatic conditions have altered very little during the last 5-6000 years.

2.1.5. Sea-level change

Comprehending change in sea-levels is vital if we are to understand changes in human settlement patterns and activities in the coastal zone. The Arabian Gulf represents a marginalised component of the tropical Indo-Pacific Ocean. Low sea levels during the Pleistocene left the Arabian Gulf completely dry except for a narrow strip along its northern edge which carried the fresh water of the Tigris, Euphrates and various other lesser streams to a coastline located somewhere in the present day Strait of Hormuz. It was not until the Holocene transgression about 17,000 years ago (ca. 15,000 cal BC) that the level of the sea began to rise. During the past 7000 years the sea level has been fairly stable around its present location (Sheppard et al 1992). During the Holocene there have been however a number of fluctuations, the sea rising and falling a number of times. This is confirmed by the sea level change curves obtained from Failaka Island in Kuwait (Dalongeville 1990), Bahrain (Boucharlat et al. 1991) and Umm al-Qaiwain (Bernier et al. 1995).

As with the evidence for climate change there appear to be major discrepancies in the opinions of different researchers who have investigated sea level change in the Gulf. A summary of all the published sea level data is presented in Table 2. Most authors seem to agree that its maximum extent was only 1-2 metres above present day levels, and that the maximum height was obtained around 6000 BP (4000 BC). Sea levels attained their present levels around 1000 AD.

2.2. Historical and archaeological background to the study region

2.2.1. Early documents

The Gulf's geographical location at the crossroads of three continents has led it to be explored and inhabited for millennia. Some of the earliest references to the region occur on inscribed clay tablets dating to the Late Uruk period (c. 4th millennium BC). Other evidence includes various 3rd millennium BC royal inscriptions such as those by Ur-Nanše, King of Lagash, present day southern Iraq. These provide details of the trade with Dilmun, which may refer to Bahrain (Potts 1990a: 88) or indeed also to its adjacent areas. The inscriptions of Sargon of Agade mention the "Lower sea", interpreted as being the Gulf, as opposed to the "Upper sea" which is seen as being the Mediterranean (Bosworth 1980: 17; Potts 1990a: 136; Wilson 1928: 26).

Documentary evidence suggests that the Assyrians, Babylonians and Persians all used the Gulf as a trade route between Mesopotamia and southern Arabia. Herodotus discusses the Arabian peninsula from about 600 BC. It is not described in much detail though until the Roman writer Arrian (AD 86-160) recounts the 326-325 BC journey of Nearchus, the Admiral of Alexander the Great. Nearchus voyaged from the mouth of the Indus up through the Gulf of Oman and then into the Arabian Gulf, or Erythraean Sea, as it was known at that time to the Greeks. This was the first detailed description of the islands, coastline and peoples of the Gulf. Other classical writers like Eratosthenes and Strabo also provide brief mentions of the Gulf in the early centuries AD. The famous trader's guide to the Red Sea and Indian Ocean of around 100 AD called "The Periplus of the Erythraean Sea" (Huntingford 1980) gives a further insight into life amongst coastal communities in this region. Both Arrian's "Indica" and the anonymous "Periplus of the Erythraean Sea" refer to certain coastal communities of the Arabian and Makran coasts as being the "Ichthyophagi" or "Fish-Eaters", suggesting that fishing played an important part of their lifestyle.

2.2.2. Travellers, traders and explorers

Various Muslim historians and geographers provide details of life and trade in the area, particularly during the early Islamic period when exotic goods were being traded through the Gulf. These include Ibn Hawqals "Surat al-ard" (late 4^{th}-10^{th} century AD), Ibn al-Mugawir's "Ta'rih al-Mustabsir" (early 7^{th}-13^{th} century AD), Marco Polo's travels from the late 13^{th} century and Ibn Battutah's "Rihlah" from the second quarter of the 8^{th}-14^{th} century.

Substantial European contacts with the Gulf began in the early 16^{th} century AD when the Portugese explorer and chronicler, Affonso da Albuquerque sailed into the Straits of Hormuz. After the capture of Khor Fakkan on the east coast of the UAE (Wilkinson 1964: 346), he sailed into the Gulf to protect Portugese trade interests and attacked the island of Hormuz (Marlowe 1962: 346).

2.2.3. The Portugese and the British

From that point until the early 17^{th} century the Portugese had a political and commercial stranglehold over the Gulf. This was not broken until the English eventually established a presence in Hormuz to develop their own trade in silk with Persia (Steensgard 1973: 324). The British became further involved in the region from the late 18^{th} century onwards due to various economic and political impetuses. Explorers from other countries did visit the region however at this time, the most famous of which was the Dane, Carsten Niebuhr, who visited Yemen, Oman and the Makran coast of Iran during the 1760s. Various members of the British Indian army and navy also passed through the area during the early 19^{th} century. These included a number of authors: Lt. G.B. Kempthorne followed Nearchus' route along the Iranian coast (Kempthorne 1835); Lt. F. Whitelock spent some time off Hasab on the Musandam peninsula (Whitelock 1838a,b,c); Lt. Col. L. Pelly published a note on the tribes, trade and resources of the coast of the Gulf (Pelly 1863); and, Pengelly described in some detail the communities living on the Batinah coastline of Northern Oman (Pengelly 1860). The pearl trade was one of the main sources of livelihood for the coastal communities of the southern Gulf at this time.

Britain maintained its physical presence in the area largely to preserve its imperial trade and mail route, although it became troubled by "piracy". This subsequently led to a number of "truces" from 1820 onwards, culminating in the "perpetual maritime truce" of 1853, by which the Arab sheikhs received protection from British forces in return for ceasing their pirate attacks at sea. In 1892 the United Kingdom entered into separate, although identical, treaties with the rulers of the Trucial States (also known as Trucial Oman), where the sheikhdoms became British protectorates, but continued to be autonomous. By this time more systematic and detailed accounts begin to be kept concerning the coastal communities of this region. One of the most important of these was the "Gazeteer of the Persian Gulf, Oman and Central Arabia" published by J.G. Lorimer (Lorimer 1908-15).

In 1952 the Trucial Council was established. This was a local body comprising the rulers of the seven Sheikhdoms. Following Britains decision to terminate its colonial presence east of Suez by 1971, the Trucial States began discussions to form a new partnership. In 1971, following three years of negotiations, the seven semi-autonomous sheikhdoms of Abu Dhabi, Dubai, Ajman, Sharjah, Umm al-Qaiwain, Ras al-Khaimah and Fujairah established a federal entity which is today recognised as the UAE.

2.2.4. Previous archaeological and palaeoeconomic research

The history of archaeological research in the Arabian Peninsula, and in particular within the Gulf region, is comparatively short compared with many parts of the world. Serious archaeological investigations did not begin until 1958 when oil-workers discovered archaeological remains whilst working on the island of Umm an-Nar, close to Abu Dhabi. Subsequently a Danish team of archaeologists, led by Geoffrey Bibby, was encouraged to investigate the remains (Bibby 1970; Frifelt 1991, 1995). Since that time, teams of archaeologists from Australia, Belgium, Denmark, France, Germany, Iraq, Japan, Spain, Switzerland, UK and the USA, as well as archaeologists associated with various local authorities have carried out surveys and excavations throughout the UAE. This work has culminated in the discovery of archaeological sites ranging in date from early prehistoric times to the Islamic period. Some of the major sites which are representative of the major chronological periods are presented in Table 3 (see also Figures 9-10 for the location of these sites).

No clear unequivocal evidence of palaeolithic sites have been identified along the coastal areas of the Gulf. The earliest post-Pleistocene archaeological component in the Arabian

Gulf / SE Arabia is the so-called blade-arrowhead tradition, first identified as "Qatar B" (Kapel 1967; Tixier 1977). It is now clear that this dates to no earlier than the late 6th/early 5th millennium BC. One of the only sites dating to this period with a bone assemblage which has been analysed is Al-Buhais in Sharjah, UAE (Uerpmann and Uerpmann 2000). Al-Buhais is located some 60 km in the interior of the northern Oman peninsula (Figure 9, no.16). This is a truly remarkable aceramic Neolithic site comprising a graveyard of more than 275 individuals, as well as a large number of adjacent firepits. Its inhabitants retained domestic animals like sheep and goat as well as cattle. Wild animals which were hunted included wild ass (*Equus africanus*), wild camel (*Camelus* sp.), oryx (*Oryx lucoryx*), gazelle (*Gazella* sp.) and wild goat or ibex (*Capra* sp.). Radiocarbon dates from ash in pits at the site cluster around 4700 cal BC and span a time period between about 5100 and 4200 cal BC. No fish remains were found at this site.

There is now substantial archaeological evidence confirming that the peoples of the Gulf had extensive contacts with a number of outside regions, particularly during the following period. Pottery from the Ubaid civilisation of southern Mesopotamia (c.5000-3100 BC) has now been found at a number of sites along the Saudi Arabian western seaboard of the Gulf (Burkholder 1972; Masry 1974), as well as in the lower Gulf along the coastline of the UAE (Boucharlat et al. 1991; Haerinck 1991; Millet 1991; Flavin and Shepherd 1994; Uerpmann and Uerpmann 1996; Beech and Elders 1999; Phillips forthcoming; Shepherd et. al. forthcoming). The populations inhabiting the coast appear to have an economy based on hunting, gathering and fishing. Some sites appeared to be extremely specialised such as the dugong butchery site reported on Akab island in the Umm al-Qaiwain region of the UAE (Prieur and Guerin 1991). Recent work has also confirmed the evidence from al-Buhais that some of these early communities also had domestic animals, e.g. sheep/goat occurred at both Dalma island and at Umm al-Qaiwain (Table 4; Figure 10, no's. 6 and 20), where cattle were also present (Beech 2000; Mosseri-Marlio forthcoming). Radiocarbon dating of the site on Dalma island now confirms a broadly similar date to that of al-Buhais (Beech 2000; Beech and Shepherd forthcoming). Fish remains have been recovered from a number of 5th-4th millennium BC sites in the Gulf and these will be discussed in more detail in Chapter 4.

The temporary fall in sea-level during the fourth millennium BC (Table 2) meant that sedentary fishermen may have moved closer to the shoreline. By the time of the Hafit horizon in the early 3rd millennium BC such sites may have been innundated as the sea rose yet again. This may account for the apparent lack of coastal sites dating to this period (Potts 1990a: 62). At the oasis of Hili 8 in the interior of the Oman peninsula (Figure 9, no. 12) it is clear that the inhabitants were already exploiting a range of plant and animal species by Period I of the settlement. These included a wide range of domesticated cereals like emmer (*Triticum dicoccum*), bread wheat (*T. aestivum*), two-row (*Hordeum distichon*) and six-row hulled barley (*H. vulgare*), six-row naked barley (*H. vulgare* var. *nudum*), as well as dates (*Phoenix dactylifera*), wild oats (*Avena* sp.) and jujube seeds (*Zizyphus* sp.). The presence of domesticated sheep and goat along with cattle, equids, dog and camel were also noted (Cleuziou 1982).

The period from c. 2500-2000 BC is known as the Umm an-Nar period, after the type site located on a small island off the coast of Abu Dhabi in the UAE (Figure 9, no. 11). Danish excavations carried out between 1959-65 provided a glimpse into life during the late 3rd millennium BC in the lower Gulf. A number of circular well-masoned tombs were excavated (Frifelt 1991) as well as traces of a substantial settlement (Frifelt 1995). Other important sites dating to this period were subsequently investigated at Tell Abraq (Potts 2000) and the inland oasis site of Hili 8 in the UAE (Cleuziou 1980, 1982). The economy of these sites varied according to their location. Traditional patterns of fishing and marine resource exploitation prevailed along the coastline. At the Umm an-Nar settlement the faunal remains mostly consisted of the remains of dugong (*Dugong dugon*) and green turtle (*Chelonia mydas*). Other mammals represented included domestic sheep/goat and cattle, (?wild) camel (*Camelus* sp.), oryx (*Oryx leucoryx*), gazelle (*Gazella* sp.) and two species of whale. The bird remains were dominated by cormorant (*Phalacrocorax* sp., ? probably the Socotra cormorant, *Phalacrocorax nigrogularis*), with a snake bird (*Anhinga rufa*), duck (*Anas querquedula*), flamingo (*Phoenicopterus* aff. *ruber*) and large heron (*Ardea bennuides*) also being represented (Hoch 1979). Although the fish remains have not been studied from the site it was reported that the fish exploited were mostly large, and that the remains included shark, sawfish and stingray. At Tell Abraq domestic cattle and sheep/goat have been recorded from the site as well as wild camel which forms an astonishing 30% of the identified assemblage during the Umm an-Nar phase of the site. Small quantities of equid were present, and considerable quantities of cormorants. Marine turtles seem to have been were regularly exploited during this period. Fish do not appear to be so important (Hans-Peter and Margarethe Uerpmann, pers. comm.). There is an apparent decrease in cattle and an increase in sheep/goat by the end of the Umm an-Nar/beginning of the subsequent Wadi Suq period. It is suggested that this may be due to pressure from overhunting and overgrazing (Hans-Peter Uerpmann, pers. comm.).

At site 520 at Qal'at al-Bahrain (Figure 9, no.5), which dates to between 2150-1900 BC, as well as many fish remains (Chapter 4.1.2; Van Neer and Uerpmann 1994), at least six or seven species of wild mammals, one bird species and at least two reptile species were identified (Uerpmann and Uerpmann 1994). Domestic mammals included sheep and goat (mostly sheep), cattle, pig and dog. Wild mammals included brown hare (cf. *Lepus capensis*), bottlenose dolphin (cf. *Tursiops truncatus*), spotted mongoose (*Herpestes auropunctatus*), wild cat/sand cat (*Felis silvestris s. margarita*), dugong (*Dugong dugon*), equid (*Equus africanus* s. ASINUS and cf. *E. hemionus*), Arabian oryx (cf. *Oryx leucoryx*), and Arabian rheem gazelle (*Gazella subguttorosa*). Reptiles included green turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*). Bird remains consisted almost entirely of Socotra cormorant (*Phalacrocorax nigrogularis*).

At Ra's al-Hadd on the coast of Oman (Figure 9, no.23), excavations at the third millennium BC site of HD1 by Dr. Julian Reade of the British Museum recovered only small quantities of terrestrial mammal remains (n=123). Dog/wolf accounted for 71% of all identifiable fragments, followed by sheep/goat (8%), cattle, equid, gazelle and fox (all less than 3% each) (Louise Martin, pers. comm.). However, the assemblage was dominated in number and weight by the remains of turtles (mostly the green turtle, *Chelonia mydas*) with moderate quantities of dolphins (Mosseri-Marlio 2000). Both these species provide valuable quantities of body fat, and cut marks identified on turtle phalanges suggest that the site's inhabitants may have been interested in hide removal, as well as the more obvious food content in these animals. The fish bones from HD1 are currently under study by Caroline Cartwright.

In contrast to the coastal sites, mixed farming and herding seems to have taken place in the inland oases like Hili 8. Domesticated sheep, goat and cattle bones, as well as a small number of equid and camel bones have been recovered from Phase 1b at Hili 8 (Hans-Peter Uerpmann, pers. comm.). Two-row barley, six-row hulled barley, emmer and jujube were also recorded as in the earlier Hafit period at the site (Cleuziou 1989).

In the northern Emirates, the settlement site of Shimal (Figure 9, no. 19) was founded during the Umm an-Nar period (Vogt and Franke-Vogt 1987). Domesticated sheep and goat (mostly goat), followed by cattle, (?wild) camel, pig, equid, gazelle, wild goat, fox, hyaena and mongoose were recorded amongst the fauna at the site (von den Driesch 1994). Bird remains were dominated by Socotra cormorant (*Phalacrocorax nigrogularis*). Large quantities of fish were also recovered and these will be discussed in more detail in Chapter 4.

The copper resources of the interior began to be exploited in earnest during this period (Potts 1990a: 149-150; Weeks 1999). Finds of slag and moulds along with finished copper/bronze objects may have been exported and tin-bronzes or tin may have also been imported to the Oman peninsula from the Indo-Iranian borderlands (Weeks 1999). Other evidence for contacts between the third to first millennia BC includes such evidence as imported ceramic vessels (or imitations of foreign styles of vessels) from Mesopotamia, Harappa and Bahrain (Cleuziou and Tosi 1989; Potts 1990a,1993b; Magee 1996a,b), soft stone vessel fragments from southern Mesopotamia (Potts 1990a: 108-110, 382), chert weights from Harappa (Potts 1990c: 42-44, 1993a: 426-427), and stamp and cylinder seals from Bahrain and Persia (Potts 1990b: 122; Potts 1990b: 113).

The early to late second millennium BC has traditionally been known as the Wadi Suq period, although the later second millennium BC tends to be now referred to as simply the "Late Bronze Age" (Christian Velde, pers. comm.), whilst the earlier period is referred to as simply Wadi Suq (or by some people as "classic Wadi Suq"). Only three major coastal sites have been investigated dating to this period: Tell Abraq in Sharjah emirate in the UAE (Figure 9, no. 14), Shimal in Ras al-Khaimah emirate in the UAE and Ra's al-Jins in Oman (Figure 9, no. 24). At Tell Abraq, Wadi Suq I appears to be a transition period. Although the main domesticates, sheep/goat and cattle, continue to be present, there is an apparent increase in fishing and new interest in the hunting of dugong during Wadi Suq II and III. Wild camel disappears altogether during Wadi Suq IV. At the settlement site at Shimal, domestic animals were mostly represented by sheep/goat with only a single cattle and fox bone being noted (von den Driesch 1994). At Ra's al-Jins (RJ-2) on the Omani coast the late Professor Sandor Bökönyi's work on the 12,554 bone fragments demonstrated that land mammals only formed less than 5% of the overall total of identified bones (Cleuziou and Tosi 2000). Sheep and goat (mostly goat), followed by domestic dog, donkey and cattle were all represented. Wild mammals were represented by wild goat/ibex, gazelle, red fox, Rüppell's sand fox and wolf. Moderate quantities of dolphin bones were also recovered. However, the majority of the faunal remains consisted of fish (67%) and green turtle (*Chelonia mydas,* 27%). Small quantities of bird remains and small mammals were also recovered. The fish bones from this site are currently under study by Jean and Nathalie Desse.

During the Late Bronze age at Shimal domestic animals were still dominated by sheep and goat (mostly goat) followed by cattle (von den Driesch 1994). Wild hunted animals included oryx, gazelle, wild goat, Rüppell's sand fox, red fox and hare. Bird remains were dominated by Socotra cormorant. At Tell Abraq, the trend towards decreasing numbers of cattle and increasing numbers of sheep and goat appears to continue.

The Iron age witnessed a dramatic expansion of settlements into new areas throughout the entire region. This presumably reflects the increased social diversity of the peoples occupying SE Arabia at this time. At Tell Abraq during the period Iron age II, we see the first appearance of domestic camels in the region (Hans-Peter Uerpmann, pers. comm.). These are smaller than their Wadi Suq wild counterparts, and have presumably been introduced to the area possibly from the region where they were first domesticated (?southern Arabia). It is possible that the hybridisation of camels may have been invented during the later part of this period, whereby the asiatic two humped bactrian and single dromedary humped camels were interbred. Historical sources suggest that hybrids definitely existed during the proto-Islamic period. First generation hybrids have the advantage of being stronger and able to carry greater loads, combining the best features of the dromedary such as speed with the strength of the bactrian (Hans-Peter Uerpmann, pers. comm.). The overall impact of the domestication of the camel on the development of trade may have been significant. Sites like Muweilah in Sharjah emirate in the UAE (Figure 9, no. 13), located some 12-15km inland from the coast, still became apparently important trading centres even though they were based within the interior. At Shimal in the northern Emirates sheep/goat (mostly goat) continue to dominate the assemblage followed by small amounts of cattle, camel, dog, pig and equid (von den Driesch 1994). Wild hunted animals include gazelle, wild goat, Rüppells sand fox, red fox and sand cat. Bird remains again mostly consist of bones from Socotra cormorants.

The site of Mleiha, located in Sharjah emirate in the UAE (Figure 9, no.17), represents one of the major sites dating to the Late pre-Islamic period in the region. Recent analysis of the vertebrate fauna from the site has revealed that domestic mammals were dominated by sheep and goat (twice as many sheep being identified as compared to goats), followed by camel, equid, cattle and dog. Wild hunted animals included mostly gazelle, followed by oryx (*Oryx leucoryx*), thar (*Hemitragus jayakari*), some sort of carnivore and red fox (Mashkour and Van Neer 1999). The fish assemblage from this site will be discussed in further detail in Chapter 4.

The Ed-Dur period is named after the type site which is located in Umm al-Qaiwain emirate in the UAE (Figure 9, no.15; Figure 102). A preliminary investigation of the fauna from this 1^{st}-4^{th} century AD site suggested a heavy reliance on marine resources, the fauna mostly consisting of molluscs, marine fish and small livestock (Van Neer and Gautier 1993). Domestic animals were dominated by sheep and goat (mostly sheep), followed by smaller quantities of cattle, chicken, dog, equid and camel. Green turtles (*Chelonia mydas*) were present but rare. Dugongs and dolphins were also noted as being present but very rare as a whole within the assemblage. Evidence for the possible importation of two animals was identified, a fallow deer (*Dama mesopotamica*) antler fragment and pharyngeal bone of a large freshwater fish (*Barbus*).

Comparatively few archaeological sites have been investigated dating to the Sasanian and Early Islamic periods in the Gulf. On the Iranian side of the Gulf at the site of Siraf (Figure 9, no. 4), the Sasanian levels (phase 1a) of the great mosque contained the following domestic animals: sheep/goat (mostly goat) dominated, followed by cattle, pig, camel, equids, dog, cat and chicken. Wild hunted animals were represented in small quantities by marine turtle, dugong, wild sheep and goat (Badstöber 2000). Large quantities of fish remains were recovered. These are discussed in more detail in Chapter 4. At the settlement site of Kush in Ras al-Khaimah, UAE (Figure 10, no. 22-24, Figure 109), the Sasanian levels were also dominated by sheep/goat (mostly goat), followed by pig, cattle, equid, dog and cat (Beech forthcoming). Wild hunted animals included marine turtle and gazelle. The fish remains from the site will be discussed in further detail in Chapter 5. Just to the north of Kush on the island of Jazirat al-Hulaylah (Figure 9, no.20; Figure 109), Sasanian/early Islamic levels included sheep/goat and camel (Beech 1998). Wild hunted animals included marine turtle and Socotra cormorants. Fish remains predominated within the assemblage, and these are discussed further in Chapter 4.

Our knowledge of the palaeoeconomy of the 8^{th}-14^{th} century AD (Abbasid, Mongol, Turkish and Princes of Hormu periods) is relatively sparse. At Siraf (phases 1b-3, mid-8^{th} – late 13^{th} century AD), domestic animals are dominated by sheep/goat (mostly goat), followed by cattle, chicken, cat, dog, pig, camel and equids (Badstöber 2000). Wild hunted animals include wild goat, marine turtle, dugong and dolphin. The numerous fish remains are discussed in Chapter 4. The 12-13th century AD levels at Kush included sheep/goat, cattle, camel, small carnivore, chicken, marine turtle and numerous fish (Beech and Pipe 1997).

At Siraf on the Iranian Gulf coast during the Portugese period (phase 4, late 13th – early 16th centuary AD), domestic animals were dominated by sheep/goat (mostly goat), followed by small quantities of cattle, horse, camel, cat, dog and chicken (Badstöber 2000). Wild hunted animals were represented by a single fragment of dugong.

One of the most important archaeological sites dating to the Portugese period is the site of Julfar located in the northern Emirates (Figure 9, no.18; Figure 109). This coastal port is mentioned in a number of early documents and maps including the 8th century Oman Chronicle. Idrisi writing in the 12th century describes Julfar as a village of pearl fishermen. The prosperity of the settlement became further enhanced under the political authority of the Kings of Hormuz and subsequent Portugese domination. An international excavation project was set up in 1988 to investigate this important site by the National Museum of Ras al-Khaimah. This included teams of archaeologists from France, Germany, Great Britain and Japan. In the French team's excavations at mid-14th-16th century Julfar, domestic animals were dominated by sheep/goat (mostly goat). The majority of these were killed (nearly 50%) prior to 8 months, suggesting a strategy optimised towards meat production, although some individuals were retained up to their fourth year possibly for milking (Desse and Desse-Berset 2000: 91). Other domestic animals represented included cattle, camel, horse and ass. Wild hunted animals were rare within the assemblage, although some bones of gazelle and a complete green turtle (*Chelonia mydas*) carapace were discovered on the excavation. A notable discovery at the site was the presence of four adult hyaena skulls, along with the post-cranial bones of a very young individual. One of these adult skulls had cut marks visible on its palate. It is suggested by Desse and Desse-Berset (2000: 91), based on Ibn Sin's 11th century AD treatise on Arabian medicine - "Qanun fil-tibb", and Dawud al-Antaki's 16th century AD work entitled "Tadhkira 'uli al-albab", that this may be related to some form of traditional medicine. Other remains found at Julfar included a single dugong tooth which may have been introduced to the site as "ivory" for working (Desse and Desse-Berset 2000). Fish remains were abundant at the site (Chapter 4).

In the Japanese excavations at mid-14th-16th century Julfar, a similar pattern was observed, domestic animals being dominated by sheep and goat (Beech 1998). The presence of dog was also noted. Wild hunted animals included marine turtle. Fish remains were also abundant (Chapter 4).

Our knowledge of the palaeoeconomy of the Late Islamic period from archaeology is surprisingly limited as few sites have been excavated in detail with the systematic recovery of faunal remains. Archaeological work has tended to concentrate on earlier time periods and where Late Islamic sites have been investigated these have tended to be predominantly building or architectural surveys. In the 17-18th c. AD levels at Kush, sheep/goat (mostly goat) predominate, cattle, camel, small carnivore and camel are noted (Beech and Pipe 1997). Wild hunted animals included marine turtle and dolphin. Fish remains were also noted as being common.

2.3. Summary

In this chapter a description of the environmental and archaeological background to the study region has been presented. After defining the study area, the regional characteristics of the Gulf are considered. There are clear differences in depth, bottom type and salinity levels between different areas of the Gulf. Although the region as a whole is classed as subtropical there are marked differences in air and water temperature between the winter and summer months. Comparing temperature and salinity data from within the southern Gulf as well as outside the Gulf in the Gulf of Oman, there appears to be a marked gradation with more extreme conditions being witnessed as one heads into the Gulf and westwards towards Abu Dhabi waters. Research into past climatic conditions suggest that the area underwent a slightly wetter (more humid) climate between about 9000 – 6/5000 BP (c. 7000-4000 BC), with hyper-arid conditions emerging since that latter date up to the present day. Investigations into sea-level changes indicate that the Gulf is a comparatively young sea only having been filled in by the Western Indian Ocean since c. 17,000 BP (c. 15,000 BC). Sea levels reached their maximum height around 6000 BP (4000 BC) when the level was about a metre above that of the present.

Past archaeological and palaeoeconomic research has revealed that the earliest sites in the region date to the late 6th-early 5th millennium BC. Traditional patterns of fishing and marine resource exploitation prevailed along the coastline. Small quantities of domestic animals are present at two sites (Dalma island and Umm al-Qaiwain) suggesting that herding of sheep/goat as well as cattle (At Umm al-Qaiwain) would also have been practiced. Sites like al-Buhais in the interior of the Oman peninsula perhaps suggest that specialised hunter-pastoralists operated in some areas of SE Arabia. Such communities may have travelled between the coast and interior as part of their seasonal resource procurement strategies, returning to their ancestral burial grounds in the interior with their domestic herds in search of pasture in the higher more mountainous areas of the northern Oman peninsula (Uerpmann and Uerpmann 2000). During later periods there is little evidence for any significant degree of change on coastal sites, a major emphasis being placed on exploiting marine resources in combination with the herding of small ruminants, usually goats, and the occasional hunting of other wild mammals like gazelle. In the inland oases like Hili 8 the economy seems to have been based upon a combination of mixed farming and herding. The exploitation of copper resources in the mountains of the northern Oman peninsula from the 3rd millennium BC, and import of tin/bronze from the Irano-Indian borderlands, opened up new trade and contacts to the region. Domestication of the camel during the Iron age may have further spurred the intensification of trade activities. During the Ed-Dur and late-Pre-Islamic periods two sites are notable in that more of those ovicaprine remains which could be positively identified as being either sheep or goat belonged to sheep (Van Neer and Gautier 1993; Maskhour and Van Neer 1999). This may indicate that such animals were being introduced and traded to these sites from other regions. During the Sasanian period the emphasis seems to return to goat husbandry along with the exploitation of marine resources. The presence of pig at Siraf on the Iranian coast as well as at Kush in the northern Oman peninsula (Badstöber 2000; Beech forthcoming), suggests that the movement of animals was clearly taking place from the heart of the Sasanian empire in Iran to the newly established colonies across the Gulf. The wild boar (*Sus scrofa*) is not native to the Oman peninsula but is known from Iran (Harrison and Bates 1991: 211, fig. 301). The economy of the Islamic period continues to be largely based on the husbandry of small ruminants as well as the exploitation of marine resources.

The following chapter will discuss the modern and traditional fisheries of the Gulf and how these are affected by regional variations in the environmental conditions discussed in this chapter.

CHAPTER 3

THE MODERN AND TRADITIONAL FISHERIES OF THE ARABIAN GULF AND GULF OF OMAN

The aim of this chapter is to review the modern and traditional fisheries of the Arabian Gulf and Gulf of Oman.

- How many (and which) fish are present in the region?
- What are the characteristics of modern fisheries data from each of the sub-regions throughout the area?
- Is there any indication of the marked seasonal occurrence of particular fishes in certain locations within the study area?
- Are certain fish associated with particular habitats within the study area?
- What modern fishing methods are used to catch the present day ichthyofauna?
- What traditional methods are utilised in the Arabian Gulf, and particularly along the coastline of the United Arab Emirates, to catch fish, and do particular methods target specific species?

After summarising the origins of the Arabian Gulf ichthyofauna, there is a brief review of modern fisheries research in the region (section 3.1). This is followed by a state by state review of the modern fisheries data for Kuwait (section 3.2), Saudi Arabia (section 3.3), Iran (section 3.4), Bahrain (section 3.5), and Qatar (section 3.6). The United Arab Emirates (UAE) is subdivided into three main regions (justified by the environmental and ecological parameters discussed in Chapter 2.1.2-3). These sub-regions are: the Abu Dhabi coastline (section 3.7.1), the Northern region (3.7.2), and the east coast/Gulf of Oman (section 3.7.3). Following this there is a discussion of the biology of some of the important fish caught in UAE waters (section 3.7.4). Capture methods utilised in the modern fisheries of the Arabian Gulf are then discussed (section 3.8). Finally, there is a review of traditional fishing techniques used in the Arabian Gulf, and particularly along the coastline of the United Arab Emirates.

3.1. How many (and which) fish are there in the Gulf ?

The Arabian Gulf is generally believed to have reached approximately its present level around 6000 B.P. during the Holocene (Chapter 2.1.5). The species of fish now living in the Gulf had nearly completely evolved by the Pleistocene (Greenwood et al. 1966). This means that pre-Pleistocene historical factors do not account for the formation of the taxa now existing there. The present day fish fauna of the Gulf was therefore established by the penetration of species from the Indian Ocean through the Gulf of Oman and Straits of Hormuz.

Although high levels of endemism have been supposedly reported for Arabian Gulf fish, in actual fact a very low number of species (if any) exist solely within the Gulf (Jerry Kemp, pers. comm.). Kuronuma and Abe (1986: 298) only report that 7 (1.5%) out of a total of 465 species present within the region are endemic species. This is because most of the species present (89%) are derived from both the Indian and Pacific Oceans, a smaller number (11%) being restricted to the Indian Ocean.

Table 5 presents a summary of major research on fisheries in the Arabian Gulf and Gulf of Oman. One of the major problems faced in going through the literature is the plethora of names and synonyms which exist for Arabian Gulf fish taxa. This is further complicated by the fact that a great number of misidentifications are present within the existing literature. The recent publication of Randall's "Coastal Fishes of Oman" (Randall 1995) along with the FAO Field Identification Guide by Carpenter et al. (1997) have fortunately summarised many of these and represent the most recent attempts to update the taxonomy and description of fishes in the region. These are the two key bibliographic resources which are referred to in the present study. Appendix 1 summarises the taxonomy, size and habitat preferences of the main fish taxa referred to in this study.

Various opinions exist concerning the precise number of fishes present within the Arabian Gulf and it is clear that many earlier records of species are questionable (Randall 1995). A further problem is that many published accounts do not provide detailed distribution data and it is not possible to determine if a particular species occurs in the Arabian Gulf or in the Gulf of Oman or in both (e.g. Relyea 1981; White and Barwani 1971). What is clear however is that there appears to be some variation in species richness throughout the Gulf.

The deeper waters of the northern part of the Gulf and along the Iranian coastline are noted as being richer in species than the southern region. Studies have shown that habitat area (MacArthur and Wilson 1967) and its differentiation into zones (Goldman and Talbot 1976; Roberts 1986) can affect species richness. It has also been demonstrated that trends in butterflyfish species richness and abundance in the Red Sea correlate closely with reef development patterns (Roberts et al. 1988). The harshness of the environmental conditions in the Gulf (e.g. extreme temperatures and high salinity) certainly appear to inhibit reef growth (Downing 1985; Sheppard 1988), and it is likely that this has reduced species richness within the region.

Despite the fact that marine ecological research in the region dates back as far as the Danish expedition in 1775, which involved Forsskål, comparatively little is still known about the Arabian Gulf marine fauna. Although there have been a number of publications specifically concerning Gulf fishes (e.g. Al-Baharna 1986; Al-Sedfy 1982; Kuronuma and Abe 1972, 1986; Relyea 1981; Sivasubramaniam and Ibrahim 1982; White and Barwani 1971) these have been criticised in recent years for including many records based on old literature rather than on actual specimens (Randall 1995). In the more recent survey by Randall (*op.cit.*) he specifically mentions that at least 95 families and 361 species are present within the Gulf as a whole. Several of the species he discusses in his book are classed as "widespread in the Indo-Pacific" so some of these may also be present in the Gulf. The few systematic surveys which have been carried out in the Arabian Gulf using SCUBA-equipped observers have concentrated on reef fish assemblages which appear to be far less diverse than elsewhere in the Indian Ocean (or even in the Red Sea at a similar latitude). Downing (1985) counted only 85 species on Kuwaiti reefs. Basson et al. (1977), McCain et al. (1984) and Coles and Tarr (1990) only 70, 101 and 106 species respectively along the east coast of Saudi Arabia. Smith et al. (1987) only 72 species in reefs off the coast of Bahrain. Roberts (quoted in Sheppard et al. 1992) observed only 35 species during a 10 hour observation of inshore reefs in Qatar. Unfortunately comparatively little is known about the fish fauna of the UAE Gulf coastline. The few popular publications which exist suggest however that the number of species present is also low in number (Dipper and Woodward 1989). According to the director of the Ministry of Agriculture and Fisheries Marine Resources Research Centre in Umm al-Qaiwain, Mohamed Abdel Rahim Hassan (pers.comm), there are at least 138 fish species present within the coastal waters of the UAE, although it is uncertain what this figure is based upon. However, the Ministry of Agriculture and Fisheries in the UAE has carried out a number of fish landing surveys (Ali and Thomas 1979; Ali et al. 1980; Ali and Cherian 1983). These data are discussed in further detail later in this chapter in part 3.3.

One of the most recent reviews of the demersal fisheries of the Arabian Sea, Gulf of Oman and Arabian Gulf has noted the presence of over 350 commercial fish species in this entire area (Siddeek et al. 1999). Primary familes represented were emperors (*Lethrinidae*), seabream (*Sparidae*), groupers (*Serranidae*), rabbitfish (*Siganidae*), croakers (*Sciaenidae*), butterfishes/pomfrets (*Stromateidae*), snappers (*Lutjanidae*), cutlassfishes (*Trichiuridae*) and breams (*Nemipteridae*). Fishing effort in the Arabian Gulf was observed to be above the optimum level, and they suggest that reduced fishing effort, strictly enforced closed seasons and closed areas are urgently required.

The modern fisheries research for each region of the Gulf will now be discussed. This will be carried out on a country by country basis largely because much of the data are only available in this format. In actual fact there appear to be quite strong regional differences between the different areas of the Gulf so by adopting a state by state review these act as proxy indicators for general regional environmental/ecological trends.

There has been an unequal amount of research effort put into investigating the modern fisheries within these different areas. More work has been carried out in Kuwait in the northern Gulf, as well as on the Saudi Arabian Gulf coast, as a result of various factors like the existence of a Marine Research Laboratory in the Kuwaiti Institute of Scientific Research (KISR), studies sponsored by oil companies and MEPA/IUCN on the Saudi Arabian coast, as well as follow up studies and surveys after the Gulf War. Much of the output from this research is sadly only available in the form of government reports or other "grey literature" which is often difficult to obtain.

3.2. Kuwait

Kuronuma and Abe (1972) published "Fishes of Kuwait" in which they include 131 species of representative forms commonly met in Kuwait. Unfortunately it is not clear in a number of cases if particular species occur in Kuwaiti waters or elsewhere in the Gulf, and in a few cases even from outside the Gulf. They note though that fishing is conducted from Kuwait throughout the year except in the winter season during December and January when the wind directions are not suitable.

Hussain and Abdullah (1977) analysed the length-weight relationship, spawning season and food habits of six commercial fishes found in Kuwaiti waters. These were the orange-spotted grouper (*Epinephelus coioides*), silver grunt (*Pomadasys argenteus*), yellowfin seabream (*Acanthopagrus latus*), sobaity seabream (*Sparidentex hasta*), tigertooth croaker (*Otolithes argenteus*) and silver pomfret (*Pampus argenteus*). They noted that the peak spawning season for these fishes occurred in the spring-time, from February to May. The maximum size for many of these species was encountered in catches during April to May.

Gubanov and Shleib (1980) examined hydrological and fisheries data in Kuwaiti waters. They undertook a trawl survey and listed the relative importance of the various fish species present in Kuwaiti waters (Table 6). Their study confirmed the importance of fish like black pomfret (*Parastromateus niger*), groupers (*Epinephelus* spp.), grunts (*Pomadasys* spp.), seabream (*Acanthopagrus* spp. and *Argyrops spinifer*), croakers (*Otolithes* spp.), silver pomfret (*Pampus argenteus*), and spotted spanish mackerel (*Scomberomorus guttatus*). Other valuable species which were seldom caught in trawls included snappers (*Lutjanidae*), emperors (*Lethrinidae*), and the narrowbarred spanish mackerel (*Scomberomorus commerson*). Fish such as the sea catfish (*Ariidae*) were reported as being numerous but largely ignored by the modern day fisheries of the region. Half of all the sharks caught belonged to the whitecheek shark (*Carcarhinus dussumieri*). They report that only one species of ray, the giant guitarfish (*Rhynchobatus djiddensis*), is used as food. Other species including various species of jack (*Carangidae*) like *Carangoides* spp., *Caranx* spp., *Decapterus* spp., *Megalaspis cordyla*, are reported as being scarcely used species.

Morgan (1985) summarised the status of shrimp and fish resources in the Arabian Gulf and noted that 7338 tonnes of fish were landed by all fishing methods in Kuwait during 1984 (Table 7). Groupers formed a quarter of all the fish caught during 1984 in Kuwaiti waters, with snappers (14%), grunts (11%) and mullets (10%) being the next most important families.

A survey of the fish fauna of the Arabian Gulf by Kuronuma and Abe (1986) noted that 244 species from 101 families were present, including 18 species of Chondrichthyes and 226 species of Osteichthyes. A total of 88 species were obtained at the two fish markets in Kuwait and Basrah in Iraq. They noted that thirteen families held ten or more species and these included jacks (*Carangidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), gobies

(*Gobiidae*), herrings, sardines and shads (*Clupeidae*), groupers (*Serranidae*), seabream (*Sparidae*), requiem sharks (*Carcharhinidae*), cardinalfish (*Apogonidae*), croakers (*Sciaenidae*), blennies (*Blennidae*), lefteye flounders (*Bothidae*) and tuna/mackerel (*Scombridae*). They observed a marked difference in the occurrence of particular species within the Gulf. The total number of species collected in the NW waters of the Gulf off the coast of Kuwait was 184, whereas only 129 species were collected in the SE waters of the Gulf off the coast of the United Arab Emirates. This means that almost double the number of species were observed in the NW to the SE (Kuronuma and Abe 1986: 279). Amongst their other interesting observations was the fact that sharks, rays and skates were rarer in SE compared with NW waters. More species of grouper (*Serranidae*) abounded in the NW rather than SE waters. Species of jack (*Carangidae*) occurred nearly twice as often in the NW as in SE waters. Amongst the *Haemulidae*, more species belonging to the genus *Plectorhinchus* and *Pomadasys* were identified in the NW than the SE waters. Emperors (*Lethrinidae*) were more abundant in the SE rather than the NW. Seabream (*Sparidae*) were as a whole more abundant in the NW than in the SE. Croakers (*Sciaenidae*) were only identified in NW waters. Bothid flatfishes were more abundant in the SE. It is apparent that environmental factors in the NW Gulf allow a greater number of species to live there than in SE waters. The factors causing this difference may be the deepness of the water, different abundance of benthic animals and the nature of bottom deposits between the two areas.

Some work has been carried out on the aging of Kuwaiti fish using otoliths (Williams 1986). This and earlier work by Matthews and Samuel (1983), has found that many fish species migrate from offshore to inshore for breeding or feeding in the spring-summer period, when catch rates for fish increase in Kuwaiti waters. There are many juveniles in the coastal waters during the summer season as many fish species spawn in Kuwaiti waters between the late spring to early fall. Kuwait Bay, in particular, has been identified as an important nursery ground for both shrimp and finfish, and abundant quantities of some fish larval taxa have been recorded there (Houde et al. 1986).

Abu-Hakima (1987) made a detailed study of the reproductive biology of the grouper, *Epinephelus coioides* (referred to as *E.tauvina* in the actual publication), in Kuwaiti waters. It was noted that the species had one major spawning period from April to May, and that this was associated with increasing water temperatures and relatively low salinity.

Downing (1987) undertook an extensive survey of the corals and coral reef fishes of Kuwait. He identified a total of 119 species from the coral reefs of Kuwait. This forms a high proportion of the total number of species known within the northwestern Gulf. Fish censuses were undertaken over a two year period at two locations on each of the major reefs in Kuwait, Kubbar, Qaru and Imm Al Maradem. The survey involved underwater transects using a visual census technique. The results of this work demonstrated that there was a marked seasonal fluctuation in the numbers of fish. Downing observed that the reefs supported a number of commercially important fish, some of which utilised the reefs as breeding areas. He also made a number of interesting observations in relation to the fishes present in Kuwaiti waters. Sharks and rays were poorly represented on the coral reefs of Kuwait. Other cartilaginous fishes were seldom encountered on the reefs and are therefore probably more common off the reef edge and away from the main reef (Downing. 1987: 12). *Tylosurus* sp. was the sole needlefish (*Belonidae*) species collected from the reefs. Although Koronuma and Abe (1986) reported collecting eight species of grouper (*Serranidae*) in Kuwaiti waters, this study only reported four species from Kuwait's coral reefs (Downing (1987: 13). The halfspotted hind (*Cephalopholis hemistiktos*) was the most abundant species. He observed that the grouper species, *Epinephelus coioides*, tended to prefer reef edge areas, although it could be also seen in shallow depressions in the sand. Other coral reef groupers present included *E.caeruleopunctatus* and *E.multinotatus*. The golden trevally (*Gnathanodon speciosus*) is a crustacean feeder and was only occasionally recorded searching for food in the bottom sediments. The most common jack recorded on the reefs was the orangespotted jack (*Carangoides bajad*). These fish often swam up to and circled divers. Although the yellowtail scad (*Atule mate*) was not observed on any of Downing's sample transects he did note that this species was found in very large schools off the northern edge of Qaru in the spring (Downing 1987: 15). Snappers (*Lutjanidae*) were represented by two species. The more common species was the blackspot snapper (*Lutjanus ehrenbergi*). This was more common during the months of July and August. It formed schools of 50+ fish which often congregated under large coral overhangs or *Acropora* tables. The larger more elusive species, Russell's snapper (*Lutjanus russellii*), was not seen on his transects. Three species of grunts (*Haemulidae*) were recorded. The most common species was the sordid sweetlip, (*Plectorhinchus sordidus*). A breeding aggregation of this species was observed at Qit'at Urayfijan, one of the inshore reefs, in June 1985. The blackspotted rubberlip, (*Plectorhinchus gaterinus*), was occasionally seen, and the trout sweetlips, (*Plectorhinchus pictus*), was very rare. Two species of emperors (*Lethrinidae*) were observed on the reefs. These both occupied quite different niches. Whilst the spangled emperor (*Lethrinus nebulosus*) was usually seen just off the edge of the reef in mid-water and only occasionally strayed above the reef itself, the snubnose emperor (*Lethrinus borbonicus*) generally remained close to the bottom near to coral shelter. Downing noted that both were quite rare occurrences on the transects. Only three genera of seabream (*Sparidae*) were observed on the Kuwaiti reefs, compared to the eight reported by Kuronuma and Abe (1986). He observed that the twobar seabream (*Acanthopagrus bifasciatus*) and onespot seabream (*Diplodus kotschyi*), were particularly common in the late spring and summer months, as they came to the reefs for breeding (Downing 1987: 16). Barracudas (*Sphyraenidae*) were not uncommon on the reefs, and were sometimes seen in large schools. Larger individuals were more common around platform reefs. The most common parrotfish (*Scaridae*) observed on the reefs was the Gulf parrotfish (*Scarus persicus*). Both juveniles and adults were often seen in large schools. The white-spotted spinefoot (*Siganus canaliculatus*) was the commonest rabbitfish recorded on the survey transects. Large schools of this species were seen at Qary during the spring, and running males were caught during the late spring and early summer. This suggests that the reefs may be one area where this fish breeds. The other rabbitfish species present, dusky spinefoot, (*Siganus luridus*), was much less common. Although tunas and mackerels (*Scombridae*) were only occasionally recorded, the Indian mackerel (*Rastrelliger kanagurta*) was seen in very large schools just off the reef northwest of Qaru. It remained close to the surface where it was feeding on plankton.

Various problems exist with underwater visual census techniques. A number of authors have pointed out biases which are inherent in these techniques (e.g. Russell et al. 1978; Sale 1980; Sale and Douglas 1981; Brock 1982; Harmelin-Vivien et al. 1985). These include problems associated with underwater visibility, the disturbance of fish by the diver, attraction of some fish towards the diver, and the fact that cryptic fish may be missed and not counted (e.g. the numbers of some species like the small serranid species, yellowfin hind, *Cephalopholis hemistiktos*, may be underestimated). Nevertheless, Downing's study highlighted the very marked seasonal fluctuation of fishes present on the Kuwaiti reefs. He observed a large increase in the numbers of fish during the spring and summer months. A number of factors contributed towards this phenomenon. A number of fish clearly used the reefs as breeding/feeding grounds. This made them more visible. Some species were also not so active during the colder winter months and so were more visible during the spring and summer months. Based on his observations of the behaviour of fish on the reef, Downing noted that the reefs acted as a breeding ground for a number of species including:

the arabian carpetshark (*Chiloscyllium arabicum*), Ehrenberg's snapper (*Lutjanus ehrenbergii*), twobar seabream (*Acanthopagrus bifasciatus*), onespot seabream (*Diplodus kotschyi*), white-spotted spinefoot (*Siganus canaliculatus*) and the milkspotted puffer (*Chelonodon patoca*). Several other species were also observed in breeding aggregations or groups. These included the sordid sweetlip (*Plectorhinchus sordidus*), the Arabian monocle seabream (*Scolopsis ghanam*), the yellowbar angelfish (*Pomacanthus maculosus*), yellowtail surgeonfish (*Zebrasoma xanthurum*), moon wrasse (*Thalassoma lunare*), and the Gulf parrotfish (*Scarus persicus*).

More recently Mohammed et al. (1998) have carried out an assessment of Kuwait's post Gulf War shrimp fishery and stock status between 1991-96. They noted that the intertidal mudflats of Kuwait Bay serve as important nursery grounds for the shrimp species, *Metapenaeus affinis*.

A recent investigation of the bycatch composition from shrimp trawling in Kuwait has recognised 43 fish species of which 23 were considered to be major bycatch species (Ye et al. 2000). Between 1987-90 tigertooth croaker (*Otolithes ruber*), consistently formed the largest percentage of the catch. The next major species were mullet (*Liza* sp.), threadfin bream (*Nemipterus* sp.) and Belanger's croaker (*Johnius belangerii*). Other commercially important species found amongst the bycatch included the silver pomfret (*Pampus argenteus*), the orangespotted grouper (*Epinephelus coioides*), yellowfin seabream (*Acanthopagrus latus*) and spangled emperor (*Lethrinus nebulosus*). Non-Ariid finfish made up the majority of the discarded bycatch (53.6%), the remainder being comprised of sea catfish (*Arius spp.*, 29.7%), cat shark (*Chiloscyllium griseum*, 13.7%) and mixed guitar fish (*Rhinobatidae*, 3%). It is interesting to note here that almost a third of all bycatch consists of sea catfish. Clearly these fish are not so highly prized at the present day.

3.3. Saudi Arabia

Our knowledge of fish habitat preferences within the Gulf other than those associated with coral reef based faunas is extremely limited. The habitat survey carried out in Saudi Arabian Gulf waters by Basson et al. (1977) still represents one of the only studies of its type in the region. This research identified a number of particular characteristic habitats in the western Arabian Gulf. These included: sand beach, tidal creek, subtidal rock, subtidal sand, subtidal mud, grassbeds, coral reefs and open water (Table 10). Characteristic fish faunas were identified within each of these habitats. A brief mention will be made here of these habitats and some of the taxa present within them which have been identified on archaeological sites in the region (Chapters 4 and 5).

Sandy beach habitats included fish like anchovies (*Stolephoridae*), mojarras (*Gerreidae*), snappers (*Lutjanus* sp.) and the spangled emperor (*Lethrinus nebulosus*).

Tidal creeks included sardines (*Sardinella* sp.) and shads (*Nematolosa nasus*), flatheads (*Platycephalidae*), terapons (*Teraponidae*), mojarras (*Gerreidae*), seabream (*Acanthopagrus* sp.) and mullets (*Mugil* sp.).

Subtidal rock habitats included at least three species of grouper (*Epinephelus chlorostigma, E.coeruleopunctatus and E.coioides*) and snapper (*Lutjanus fulviflamma, L.johnii* and *L.sanguineus*), two species of grunt (*Haemulidae*), dotted bream (*Scolopsis ghanam*), three species of seabream (*Acanthopagrus berda, A.bifasciatus* and *Sargus noct*), the yellowbar angelfish (*Pomacanthus maculosus*) and rabbitfish (*Siganus canaliculatus*).

Subtidal sand habitats included the Indian flathead (*Platycephalus indicus*), the orangespotted grouper (*Epinephelus coioides),* ponyfish (*Leiognathidae*), mojarras (*Gerreidae*), two species of grunt (*Pomadasys argenteus* and *P.stridens),* notched threadfin bream (*Nemipterus peronii*), three species of emperor (*Lethrinidae*) and two species of seabream (*Acanthopagrus cuvieri* and *Argyrops spinifer*).

Subtidal mud habitats included: sea catfish (*Ariidae*), the Indian flathead (*Platycephalus indicus*), the spinycheek terapon (*Terapon puta*), two species of snapper (*Lutjanus fulviflamma* and *L.sanguineus*), striped piggy (*Pomadasys stridens*), notched threadfin bream (*Nemipterus peronii*), the king soldierbream (*Argyrops spinifer*), and rabbitfish (*Siganus canaliculatus*).

Seagrass bed habitats included: sawfish (*Pristidae*), the giant guitarfish (*Rhynchobatus djeddensis*), stingrays (*Dasyatidae*), flatheads (*Platycephalidae*), the spinycheek terapon (*Terapon puta*), dory snapper (*Lutjanus fulviflamma*), two species of grunt (*Plectorhinchus schotaf* and *Pomadasys* sp.), notched threadfin bream (*Nemipterus peronii*), emperor (*Lethrinus* sp.), four species of seabream (*Argyrops spinifer, Crenidens crenidens, Rhabdosargus* sp., and *Sargus noct*), and rabbitfish (*Siganus canaliculatus*).

Coral reefs contained the richest assortment and diversity of species. These included: requiem sharks (*Carcarhinidae*), eaglerays (*Myliobatidae*), wolf herrings (*Chirocentridae*), five species of grouper (including *Cephalopholis* and *Epinephelus* spp.), sharksucker (*Echeneis naucrates*), at least seven species of jack (including *Caranx* spp., *Gnathanodon speciosus, Trachinotus blochii* and *Ulua mentalis*), three species of snapper (*Lutjanus fulviflamma, L.johnii* and *L.sanguineus*), three species of grunt (*Haemulidae*, including *Plectorhinchus* spp.), dotted bream (*Scolopsis ghanam*), three species of emperor (*Lethrinus lentjan, L. miniatus* and *L. nebulosus*), three species of seabream (*Acanthopagrus bifasciatus, A.cuvieri* and *Sargus noct*), two species of angelfish (*Pomacanthus imperator* and *P.maculosus*), damselfish (*Pomacentridae*), parrotfish (*Scaridae*), indian mackerel (*Rastrelliger kanagurta*), narrow-barred spanish mackerel (*Scomberomorus commersoni*), batfish (*Platax* sp.), and rabbitfish (*Siganus canaliculatus*)

Open water fish included six species of requiem shark (*Carcharhinidae*), hammerhead shark (*Sphyrnidae*), two species of eagleray (*Myliobatidae*), shad (*Nematolosa nasus*), anchovies (*Stolephoridae*), wolf herring (*Chirocentrus dorab*), needlefish (*Belonidae*), cobia (*Rachycentron canadum*), sharksucker (*Echeneis naucrates*), dolphinfish (*Coryphaena hippurus*), at least 10 species of jack/trevally (*Carangidae*), including *Caranx* spp., *Decapterus* spp., *Gnathanodon speciosus, Scomberoides* spp., *Seriola* sp., *Trachinotus blochii* and *Ulua mentalis*, seabream (*Acanthopagrus cuvieri*), three species of barracuda (*Sphyraena* spp.), kawakawa (*Euthynnus affinis*), indian mackerel (*Rastrelliger kanagurta*), two species of mackerel (*Scomberomorus commersoni* and *S. guttatus*), and tuna (*Thunnus* sp.).

Hull (1979) made a provisional assessment of the fish stocks from the Gulf coast of Saudi Arabia. This was done on the basis of a trawl survey carried out by a ship from the Saudi Arabian Ministry of Agriculture and Water. He found that the amounts of fish varied in density between different areas from as much as 1 ton/km^2 to 7.6 tons/ km^2 (Table 8). A total of 66 fish families were caught by this trawling survey, including at least 103 species. Sea catfish (*Ariidae*) were only recorded over mud/sand areas. Amongst the groupers (*Serranidae*), the most common species was the orange-spotted grouper (*Epinephelus coioides*). The greatest concentration of jacks (*Carangidae*) was in the 25-50m depth band, though comparatively few jacks were caught throughout the survey area. This is probably largely because much of the trawl survey was done at night. The only jacks of any consequence caught in this survey were *Decapterus, Leptolepis* and *Selaroides*. Emperors (*Lethrinidae*) occurred throughout the study area but rarely in great concentrations. The pinkear emperor (*Lethrinus lentjan*) occurred in a much wider depth band than the spangled emperor (*Lethrinus nebulosus*). Consistently low quantities of grunts (*Haemulidae*) were recorded in the survey area. Rather low densities of goatfish (*Mullidae*) were also recorded. The survey established that many small pelagic species could only be caught in any reasonable quantity between the early morning to evening, as this is when they were concentrated on or close to the bottom (Hull 1979: 311). Other families present such as the silver bellies (*Leiognathidae*), silver biddies (*Gerreidae*), triggerfish (*Balistidae*), lizardfish (*Synodontidae*) and threadfin bream (*Nemipteridae*) were regularly found throughout the survey area but only in relatively low concentrations. The conclusion of Hull's survey was that certain areas, in particularly the 20-50m shell/gravel bottoms, had a markedly higher than average productivity.

An underwater survey of the coral reefs and reef fishes of the Saudi Arabian Gulf coast was carried out between May to October 1982 (McCain et al. 1984). This study observed a total of 106 species on these reefs, and demonstrated that the depth of the reef base was an important factor in determining the composition of reef fish communities. Various physical characteristics of the reef as well as seasonal factors affected the fish communities living within this region. Transient visitors to the reefs included sardines (*Sardinella* sp.) which were most numerous in May, and were present on inshore reefs from March through August. Other transients included the semi-pelagic piscivores: orangespotted jacks (*Carangoides bajad*), scad (*Alepes* sp.), yellowtail scad (*Atule mate*), barracuda (*Sphyraena* sp.) and needle fish (*Belonidae*). Soft-bottom dwelling fish such as the haffara seabream (*Rhabdosargus haffara*) and terapon (*Terapon puta*) were very abundant on the survey transects early in the year but moved off the reefs as the algae blooms subsided (McCain et al. 1984: 110). Commercially important resident fishes on the reef included groupers (*Serranidae*), snappers (*Lutjanidae*), seabream (*Sparidae*), rabbitfish (*Siganidae*) and grunts (*Haemulidae*). Jacks (*Carangidae*) were frequently observed feeding over the reefs, and sardines (*Clupeidae*) utilised the reefs as nursery grounds. Amongst the primary reef fish residents, there was a markedly lower abundance of fish during the early part of the year. However, the abundance of resident fishes increased rapidly by May and most peaks of abundance were observed in September. By October the abundance of fishes declined on all the surveyed reefs. During the winter months it seems likely that there is a large migration or mortality of fishes from these reefs, perhaps due to the lower water temperature (McCain et al. 1984: 112).

Morgan (1985) discussed the composition of fish catches in Saudi Arabian Gulf waters during 1977 (Table 9). Mackerel (*Rastrelliger kanagurta* and *Scomberomorus* spp.) formed the greatest annual weight (25%), followed by emperors (*Lethrinidae*, 15%), jacks/trevallies (*Carangidae*, 13%), groupers (*Serranidae*, 11%), snappers (*Lutjanidae*, 6%) and other species (30%).

3.4. Iran

Blegvad listed 70 families and 216 species of fishes as being present on the Iranian side of the Gulf of Oman (Blegvad 1944). This remains the most intensive piece of work carried out along the Iranian coast. The collection of specimens was mainly carried out by trawling. Most of the bottom in this area is mud (Figure 3), and so the range of fish recorded partly reflects this factor with ponyfish (*Leiognathidae*) and sea catfish (*Ariidae*), being caught in greater numbers there than elsewhere in the Gulf. It seems that relatively few other investigations have been published concerning the marine fauna of the Iranian side of the Gulf. However, this may be partly a false impression as further effort was made to obtain modern fisheries data for the western and southern coasts where the zooarchaeological assemblages analysed in this study were located.

3.5. Bahrain

Morgan (1985) provided the total quantities of fish landed in Bahrain annually between 1979-83 (Table 11). The majority of the catch in each of these years was composed of perches (*Perciformes*, between 20-30% of annual landings), rabbitfish (*Siganidae*, between 15-24%), groupers (*Serranidae*, between 15-19%), jacks/trevallies (*Carangidae*, between 9-15%), and snappers (*Lutjanidae*, between 3-9%). Seabream (*Sparidae*) only formed between 2-4% of annual catches, and mackerels (*Rastrelliger kanagurta*/*Scomberomorus* spp.) only between 2-6%. Other families, like needlefish (*Belonidae*), mojarras/silver biddies (*Gerreidae*), grunts (*Haemulidae*), mullets (*Mugilidae*), goatfish (*Mullidae*), sergeantfish (*Pomacentridae*), barracuda (*Sphyraenidae*) and triggerfish (*Balistidae*), only formed between 1-3% of annual catches.

The first real attempt at a survey of Bahraini fisheries was a publication by the Ministry of Commerce and Agriculture in Bahrain entitled "Fishes of Bahrain" (Al-Baharna 1986). This noted that the fishes in Bahraini waters were distinct from the northern part of the Gulf, specifically the Shat Al-Arab and Kuwait Bay region, as well as from the deeper Gulf of Oman region. The shallow waters harbouring coral reefs and islands made the fish fauna of Bahrain much more localized in character. This publication mentions 84 families and 238 species. Unfortunately it does not mention which particular species are specifically collected in and around Bahrain, and which are records from other countries in the Gulf. The publication did mention the fact though that there are clear regional differences in the fish catch throughout the Gulf. Whereas emperors (*Lethrinidae*), snappers (*Lutjanidae*) and groupers (*Serranidae*) occur more on the southern coast, off the Iranian coast, ponyfishes (*Leiognathidae*) and sea catfish (*Ariidae*) predominate. In the northern Gulf, off the coast of Iraq, mullets (*Mugilidae*) and herrings/sardines/shads (*Clupeidae*) are abundant around the Shatt al-Arab reflecting the estuarine conditions (Al-Baharna 1986: 15).

Divers using SCUBA carried out a survey of reef fishes between April to June 1985 on three reefs in 4-15m depth northeast of Bahrain (Smith et al. 1987). A total of 71 fish species from 25 families were recorded by this study. Species noted on the shallowest reefs (<7m depth) included: bamboo shark (*Chiloscyllium arabicum*), malabar grouper (*Epinephelus malabaricus*), barred jack (*Carangoides ferdau*), golden trevally (*Gnathanodon speciosus*), blackspot snapper (*Lutjanus ehrenbergii*), dory snapper (*Lutjanus fulviflamma*),. blackstreak bream (*Scolopsis taeniatus*), painted thicklip (*Diagramma pictum*), blackspotted thicklip (*Plectorhinchus gaterinus*), trout thicklip (*P.pictus*), minstrel (*P.schotaf*), smalltooth emperor (*Lethrinus microdon*), redspot emperor (*L.lentjan*) and spangled emperor (*L.nebulosus*), doublebar seabream (*Acanthopagrus bifasciatus*), onespot porgy (*Diplodus sargus kotschyi*), sobaity (*Sparidentex hasta*), pearly goatfish (*Parupeneus margaritatus*), freckled goatfish (*Upeneus tragula*), arabian butterflyfish (*Chaetodon melapterus*), blackspotted butterflyfish (*Chaetodon nigropunctatus*), longfin bannerfish (*Heniochus acuminatus*), yellowbar angelfish (*Pomacanthus maculosus*), Indo-Pacific sergeant (*Abudefduf vaigiensis*), Clark's anemonefish (*Amphiprion clarkii*), bluebarred parrotfish (*Scarus ghobban*), and pearlspotted rabbitfish (*Siganus canaliculatus*).

Species noted on the deepest reefs (13-15m depth) included: bamboo shark (*Chiloscyllium arabicum*), halfspotted hind (*Cephalopholis hemistiktos*), areolate grouper (*Epinephelus* *areolatus*), malabar grouper (*Epinephelus malabaricus*), barred jack (*Carangoides ferdau*), yellowlined snapper (*Lutjanus lutjanus*), notchfin threadfin bream (*Nemipterus peronii*), dotted and blackstreak bream (*Scolopsis ghanam* and *S.taeniatus*), painted thicklip (*Diagramma pictum*), blackspotted thicklip (*Plectorhinchus gaterinus*), sordid thicklip (*P.sordidus*), spangled emperor (*Lethrinus nebulosus*), doublebar seabream (*Acanthopagrus bifasciatus*), yellowbar angelfish (*Pomacanthus maculosus*), great barracuda (*Sphyraena barracuda*), u-spot wrasse (*Halichoeres stigmaticus*), bluebarred parrotfish (*Scarus ghobban*), persian parrotfish (*Scarus persicus*), bullethead parrotfish (*Chlorurus sordidus*), stellate puffer (*Arothron stellatus*) and milkspotted puffer (*Chelonodon patoca*).

An underwater SCUBA survey of reefs off the coast of Bahrain between June to December 1985 only recorded a total of 55 species from 22 families (Smith and Saleh 1987). The most diverse reef fish families were damselfishes (*Pomacentridae*, 5 spp.), jack/trevally (*Carangidae*, 4 spp.), grunts (*Haemulidae*, 4 spp.), seabream (*Sparidae*, 4 spp.) and gobies (*Gobiidae*, 4 spp.). Species richness increased with depth, 37 species being recorded at the shallowest survey station as opposed to 43 species at the deepest point.

Common species identified on the shallow reefs (4-7m depth) included the dory snapper (*Lutjanus fulviflamma*), onespot seabream (*Diplodus sargus*) and dark damselfish (*Pomacentrus aquilus*). Other species found in shallow waters included: striped cardinalfish (*Apogon taeniatus*), mangrove snapper (*Lutjanus argentimaculatus*), blackspot snapper (*Lutjanus ehrenbergi*), picnic seabream (*Acanthopagrus berda*), sobaity (*Sparidentex hasta*), arabian butterflyfish (*Chaetodon melapterus*), blackspotted butterflyfish (*Chaetodon nigropunctatus*), Indo-Pacific sergeant (*Abudefduf vaigensis*), Clark's anemonefish (*Amphiprion clarkii*), yellowtail tang (*Zebrasoma xanthurum*) and bluetail trunkfish (*Ostracion cyanurus*).

At the deepest station (13-15m depth) the most common species included malabar grouper (*Epinephelus malabaricus*), dotted and blackstreak bream (*Scolopsis ghanam* and *S. taeniatus*) and sind damselfish (*Neopomacentrus sindensis*). Other species found on the deep reefs included: halfspotted hind (*Cephalopholis hemistiktos*), whitespotted grouper (*Epinephelus caerulopunctatus*), blackbanded jack (*Seriolina nigrofasciata*), trout thicklip (*Plectorhinchus pictus*), giant barracuda (*Sphyraena barracuda*), parrotfish (*Scarus sordidus*), stellate puffer (*Arothron stellatus*), and milkspotted puffer (*Chelonodon patoca*).

They note that the low species richness are likely to be related to the stressful regional environmental conditions within the Gulf (Smith and Saleh 1987). Annual sea temperatures in Bahraini waters range between 12 and 36 degrees C, and salinities in the area of their survey are quite high, between 40-43 o/oo (Smith and Saleh 1987: 430).

3.6. Qatar

Tha annual production by artisanal fisheries in Qatar for 1980-81 and 1982 was investigated by Sivasubramaniam and Ibrahim (1982). During the 1980-81 season (Table 12), jacks/trevallies (*Carangidae*) formed the greatest percentage of the annual catch by weight (23%), followed by king mackerel (*Scomberomorus* spp., 21%), shark (11%), emperors (*Lethrinidae*, 8%), grouper (*Serranidae*, 7%), rabbitfish (*Siganidae*, 5%), snapper (*Lutjanidae*, 4%), grunts (*Haemulidae*, 3%), mojarra (*Gerreidae*, 2%), seabream (*Sparidae*, 2%), and tuna (*Thunninae*, 2%). Other fish families all formed less than 1% of the overall annual catch. In 1982 (Table 13), emperors formed the greatest percentage of the annual catch (16%), followed by groupers (10%), narrow-barred spanish mackerel (*Scomberomorus commerson*, 8%), rabbitfish (5%), golden trevally (*Gnathanodon speciosus*, 4%), snappers (Lutjanus spp., 4%), silver pomfret (*Pampus argenteus*, 4%), king soldierbream (*Aryrops spinifer*, 2%), trout sweetlips (*Plectorhinchus pictus*, 2%), bluebarred parrotfish (*Scarus ghobban*, 1%) and mullet (*Liza* sp., <1%).

The principal study carried out on fishes in Qatar is the book "Common Fishes of Qatar" by Sivasubramaniam and Ibrahim (1982). In relation to local environmental conditions, they note that the salinity in Qatari waters generally varies between 39-41 o/oo at the surface and tends to be 1-2% higher at the bottom. High salinity levels occur on the south-eastern coast which are sometimes over 60 o/oo. This study reported that about 54 families and 136 species commonly occur in Qatari waters. Major families included the jacks (*Carangidae*) which had over 10 common species, with groupers (*Serranidae*), snappers (*Lutjanidae*), threadfin breams (*Nemipteridae*), grunts (*Haemulidae*), seabream (*Sparidae*) and tuna/mackerel (*Scombridae*), all being represented by five or more species. They observed that the numbers of pelagic species were extremely low in Qatari waters, presumably reflecting the harsh local environmental conditions. Preliminary observations by them suggested that most species tended to spawn when the environmental conditions were moderate, such as during March and April. A number of fishes recorded elsewhere in the Gulf were not observed in Qatari waters. These include dolphinfish (*Coryphaenidae*), rainbow runner (*Elagatis bipinnulata*), black pomfret (*Parastromateus niger*), croakers (*Sciaenidae*), and butterfish (*Stromateidae*). Three species were also reported as being common in the fisheries of Qatar during the winter months which had not been recorded elsewhere in the Gulf (at that particular time). These were a species of eagleray (*Rhinoptera sp.*), sailfish (*Istiophorus platypterus*) and tuna (*Thunnus* sp.).

Sivasubramaniam and Ibrahim (1982) made a number of interesting observations about the abundance, size and seasonal occurrence of particular fish around the coastline of Qatar. Requiem sharks (*Carcharhinidae*) were common on the east and north coasts during the winter months. Bamboo sharks (*Chiloscyllium griseum*) were only seen in January and February off the north-east coast. The eagle ray species, *Rhinoptera* sp., was also common during the winter off the north-east coast. Hammerhead sharks (*Sphyrnidae*) were mainly caught from the north-east coast during the cooler winter months. Wolf herrings (*Chirocentridae*) were caught throughout the year but higher catches were made during the winter months off the north-east coast. Milkfish (*Chanos chanos*) was only common off the south-east coast during the winter months. Catches of sea catfish (*Ariidae*) were generally best in April-May, and occurred predominantly in muddy bottoms off the eastern coast. Silversides (*Atherinidae*) inhabited shallow bays in dense schools around Qatar throughout the year. Good catches of needlefish (*Belonidae*) were made during the winter months. Indian flatheads (*Platycephalus indicus*) were caught throughout the year in Qatari waters, small individuals being caught inshore and larger examples offshore. The halfspotted hind (*Cephalopholis hemistiktos*) was generally caught off the eastern and south-eastern coasts during the winter months. The most common grouper species was the orangespotted grouper (*Epinephelus coioides*). The jarbua (*Terapon jarbua*) was very common in shallow waters and was caught during all seasons along the entire eastern coast of Qatar. Cobias (*Rachycentron canadum*) were a common pelagic species present in inshore and offshore waters around Qatar. They occurred on the eastern coast throughout the year, although larger individuals were common offshore during the winter. Sharksuckers (*Echeneis naucrates*) were abundant in north-eastern waters during the winter months. Orangespotted jacks (*Carangoides bajad*) were larger in size during the winter months, and other *Carangoides* spp. were also commonly caught during the winter months. The golden trevally (*Gnathanodon speciosus*) was the most common carangid throughout the year. Smaller individuals entered the fishery in the late winter, larger individuals being caught during the summer. Young examples of the talang queenfish (*Scomberoides commersonianus*) appeared in inshore waters on the eastern coast at the beginning of the winter, larger individuals being caught offshore mainly towards the end of the summer. The greater amberjack (*Seriola dumerili*) was common during the tail end of the winter. The occurrence of the snubnose pompano (*Trachinotus blochii*) was highly seasonal, this species only occurring during the tail end of the summer off the east and south-east coast. Mojarras (Gerreidae) were fished mainly in the winter. The blackspot snapper (*Lutjanus fulviflamma*) is common along the eastern coast of Qatar during the winter when larger size fish are caught. The most common species of grunt (*Haemulidae*) observed in the Qatar fisheries was the painted sweetlips (*Plectorhinchus pictus*). This was fished throughout the year but larger individuals entered the fishery during the winter months. The grunt genus *Pomadasys* was less common than *Plectorhinchus*, and only appeared in offshore catches during December-January. The size of pinkeared emperors (*Lethrinus lentjan*) was small at the beginning of the summer and much larger in the winter. Best catches were generally made between November and March. The spangled emperor (*Lethrinus nebulosus*) was the most common species of emperor in Qatari waters, but concentrated on the eastern coast. Small sizes are caught inshore with larger fish being caught by trawls and traps during the winter. King soldierbream (*Argyrops spinifer*) were abundant in the offshore waters of the east and south-east coast of Qatar, larger individuals being caught during the winter. The doublebar seabream (*Acanthopagrus bifasciatus*) was abundant in shallow and deep water. Smaller individuals were caught during the summer and larger individuals during the winter, although they were less abundant during the cooler months. The goldstriped seabream (*Rhabdosargus sarba*) was more abundant in shallow inshore waters than in off-shore waters. This species was caught during all seasons on the north, north-east and east coasts of Qatar. Larger individuals could be caught towards the end of the winter months. The bluebarred parrotfish (*Scarus ghobban*) could be caught throughout the year along the east coast, although the peak season was during the early summer. Catches of kawakawa (*Euthynnus affinis*) were concentrated on the north-east offshore waters and Halul island. This was a moderately abundant species during the winter months but was rare in the summer. Indian mackerel (*Rastrelliger kanagurta*) was moderately abundant in Qatar waters. It too was largely caught off the north-east and east coast during the cooler months. Narrow-barred spanish mackerel (*Scomberomorus commerson*) appeared in large quantities around Qatar during the cooler months. The spotted mackerel (*Scomberomorus guttatus*) was much less abundant than *S.commerson* during the winter. Only juvenile tuna (*Thunnus* sp.) were observed by Sivasubramaniam and Ibrahim in Qatar waters. They mention though that it is frequently caught during the winter months on the east coast around Halul island

(Sivasubramaniam and Ibrahim 1982: 63). Pearlspotted rabbitfish (*Siganus canaliculatus*) was an abundant inshore species, particularly during the summer and early winter.

3.7. United Arab Emirates

One of the first fisheries surveys carried out in the United Arab Emirates was the publication entitled "Common Sea Fishes of the Arabian Gulf and Gulf of Oman" published by the Trucial States Council (White and Barwani 1971). Unfortunately this publication did not make clear which species represented actual records from within the Arabian Gulf or from the Gulf of Oman.

3.7.1. United Arab Emirates – Abu Dhabi coastline

No fisheries data has been published from the southernmost Gulf region, apart from various "grey literature" reports issued by the Ministry of Agriculture and Fisheries which simply refer to the general combined total weight of all fishes caught. The main landing site in the western Abu Dhabi region is Dalma island. The Dalma Co-operative organisation retains records of the combined monthly total weight of catch at the two market landing points on the island. Mr. Asad Shahin of the Dalma Co-operative was kind enough to provide the author with the monthly totals for January to December 1998 (Table 14). As all records are retained using the local arabic vernacular names for the fish, it is not always a simple matter to decipher these records. Dr. Saif al-Ghais, the chairman of the Environmental Research and Wildlife Environmental Agency (ERWDA) in Abu Dhabi and an eminent local fisheries biologist, kindly assisted with the translation and interpretation of these records. Whilst some of the categories recorded do coincide with particular families, genera or species, in some cases a number of different types of fish are combined. For example, sea catfish (*Arius* sp.), queenfish (*Scomberoides* sp), the smalltooth emperor (*Lethrinus microdon*), longfin bannerfish (*Heniochus acuminatus*), batfish (*Platax* sp.) as well as blue swimming crabs (*Portunus pelagicus*) are all combined as one category! Another record category includes cobia (*Rachycentron canadum*), jack (*Carangoides* sp.) and barracuda (*Sphyraena* sp.)! The grouping of these fish together may be linked to their similarity in price/value at the market where fish are quickly unloaded from the boats directly onto the quay where weights and records are noted by fisheries officers from the Dalma Co-operative.

Groupers (*Serranidae*) form the greatest percentage of the annual catch landed at Dalma island (27%), followed by trout thicklips (*Plectorhinchus pictus*, 23%), emperors (*Lethrinidae*, 16%), spanish mackerel (*Scomberomorus* spp., 16%), anchovies (*Engraulidae*, 4%), and frigate tuna (*Auxis thazard*, 2%). Other fish like sharks (mostly requiem sharks, *Carcharhinidae*), golden trevally (*Gnathanodon speciosus*), and an unknown type of fish simply referred to in the records as "yellowfish", all formed only 1% each of the annual catch.

The best fishing seasons at Dalma are during the months of May-June and November, highest catches being made in the latter month. Catches made in May-June were largely comprised of groupers, trout thicklips and emperors. In contrast, most of the November catch was formed by catches of Spanish mackerel (*Scomberomorus* spp.).

Sharks were only caught in any great number during the months of November-December. Anchovies (*Engraulidae*) were mostly caught during the early and late summer/early autumn months (June and September-October). Groupers were mostly caught in the late spring to early summer months between March-July. Barracudas (*Sphyraenidae*) were mostly caught during May and between October-December. Trout thicklips were mostly caught between May-July. Emperors were mostly caught between May-June and December. Frigate tuna were mostly caught in June. Spanish mackerel were nearly all caught between October-December (79% of the total annual catch), the majority being caught during the single month of November (51% of the total annual catch).

3.7.2. United Arab Emirates - Northern region

The only detailed published studies carried out on fisheries in the Emirates are a series of government reports made in the late 1970s to early 1980s (Ali and Thomas 1979; Ali et al. 1980; Ali and Cherian 1983; Department of Fisheries 1984; Ali et al 1984). These were a series of technical reports published by the UAE Ministry of Agriculture and Fisheries. The author was fortunate enough to obtain copies of all of these from Mohamed Abdel Rahim Hassan, Director of the Ministry of Agriculture and Fisheries Marine Resources Research Centre at Umm al-Qaiwain.

One of these reports was a detailed study of the Umm al-Qaiwain lagoon in conjunction with preparations for the experimental rearing of shrimp, rabbitfish and mullet (Department of Fisheries 1994). This publication included details of the local environmental conditions as well as a list of fish species observed within the lagoon area. The highest water temperature recorded in the lagoon was 34.4 degrees C in August, the lowest temperature being 18.3 degrees C during February. Salinity was fairly stable in the lagoon around 40 o/oo between November-May, reaching a maximum of 42.84 o/oo in July. The waters of the lagoon were found to be very rich in plankton. The bottom of the lagoon varied from soft silty bottom to seagrass on a soft silty bottom. Seagrass areas occurred sometimes in large belt-like areas or in smaller patches depending on the tide and local topography. An interesting observation was that examples of spinycheek terapon (*Terapon puta*), blacktip mojarra (*Gerres oyena*) and emperors (*Lethrinus* spp.) were found in larval or young stages throughout the year, suggesting that the lagoon was an important spawning area for these fish. All these fish were abundant in number. The pearlspotted rabbitfish (*Siganus canaliculatus*) was particularly common between May to July. In the case of the mullet species, *Liza macrolepis*, this was most abundant between February to May. A number of other fish were also reported as being abundant within the Umm al-Qaiwain lagoon (Table 15). These included: stingrays (*Dasyatidae*), Indian oil sardine (*Sardinella longiceps*), anchovy (*Stolephorus* sp.), blackfin wolf herring (*Chirocentrus dorab*), flat needlefish (*Ablennes hians*), arabian pupfish (*Aphanius dispar*), orangespotted grouper (*Epinephelus coioides*), silver sillago (*Sillago sihama*), yellowtail scad (*Atule mate*), orangespotted trevally (*Carangoides bajad*), golden trevally (*Gnathanodon speciosus*), talang queenfish (*Scomberoides commersonianus*), bigeye scad (*Selar crumenophthalmus*), dory snapper (*Lutjanus fulviflamma*), minstrel (*Plectorhinchus schotaf*), spotted grunt (*Pomadasys commersonnii*), notchfin threadfin bream (*Nemipterus peronii*), blackstreak bream (*Scolopsis taeniatus*), picnic seabream (*Acanthopagrus berda*), doublebar seabream (*A.bifasciatus*), yellowfin seabream (*A.latus*), onespot porgy (*Diplodus sargus kotschyi*), goldstriped seabream (*Rhabdosargus sarba*), mullets (*Liza macrolepis* and *Moolgarda seheli*), freckled goatfish (*Upeneus tragula*), yellowbar angelfish (*Pomacanthus maculosus*), Indo-Pacific sergeant (*Abudefduf vaigiensis*), wrasse (*Thalassoma* sp.), bluebarred parrotfish (*Scarus ghobban*), barracuda (*Sphyraena* sp.), Indian mackerel (*Rastrelliger kanagurta*) and streaked rabbitfish (*Siganus javus*).

One of the other government studies dealt with the fisheries landing data from Ras al-Khaimah during 1982 (Ali and Cherian 1983). This revealed that tuna and mackerel formed the greatest weight of annual catch (42%), followed by jacks/trevallies (13%), sardines (8%), emperors (4%), groupers (3%), sharks and grunts (2%). All other families formed 1%

or less of the total annual catch (Table 16). There were two good fishing seasons, the first being between March-May and the second during December. A closer examination of the occurrence of the major species represented (Table 17) revealed that most were caught during April or May. In the hotter summer months between June to August moderate quantities of scads, trevally, golden trevally, queenfish, tuna and rabbitfish were caught. High catches of shark and sardines were made during December. Groupers and scads were caught in good quantities during November. An interesting observation was made with regard to the timing of capture of scombrids. Whereas most tuna was caught during April-May, the best catches for Indian mackerel were between December-February, and in the case of narrow-barred Spanish mackerel (*Scomberomorus commerson*) during December when 75% of the annual catch of this species was made during a single month. Looking at each month in turn and the relative rank position of the various families (Table 18), tuna and mackerel nearly always formed the greatest weight of each monthly catch, followed by jack/trevallies, other species, emperors (between March-July), groupers (between August-November) and sardines (between December-April).

3.7.3. United Arab Emirates – East coast/Gulf of Oman

A detailed study was carried out of the fisheries landings at Khor Fakkan on the east coast of the UAE between November 1976 and October 1977 (Ali and Thomas 1979). Tuna and mackerel made up the greatest weight of the total annual catch (29%), followed by jacks/trevallies (20%), snappers (10%), groupers (9%), emperors and barracuda (6%), seabream (5%), grunts (3%), needlefish, threadfin/monocle breams and goatfish (2%). All other families formed 1% or less of the total annual catch. The best fishing month in terms of greatest weight of catch landed was April, followed by December and November. Generally catches were less seasonal than in the Gulf. This is made clear by the more even spread of shaded cells in Table 19. Closer examination of this overall picture also reveals some differences in the occurrence of particular taxa as compared with the data known from within the Gulf (Table 20). During the hotter summer months, between June-September, moderate quantities of shark, terapons, ponyfish, grunts emperors, goatfish, rabbitfish, tuna/mackerel and spiny turbots were all caught. Whereas Indian mackerel was mostly caught between November-January, similar to at Ras al-Khaimah, the majority of narrow-barred spanish mackerel were landed at Khor Fakkan between March-June, as opposed to during December in Ras al-Khaimah.

A further study was carried out of the fisheries landing data from Khor Fakkan between May 1978 until April 1979 (Ali et al. 1980). Tuna/Mackerel again formed the greatest proportion of the total annual catch (37%), followed by jack/trevallies (13%), groupers, snappers and barracuda (7%), emperors (6%), requiem sharks and needlefish (4%), threadfin/monocle breams (3%), grunts, seabream and goatfish (2%). All other families formed 1% or less of the total annual catch. The best fishing month in terms of greatest weight of catch landed was April, followed by March and February. Catches were similar to those during 1976-7, also being less seasonal in nature than those within the Gulf (Table 20). Moderate to large quantities of requiem sharks, milkfish, bigeyes, cobia, jacks/trevallies, dolphinfish, grunts, emperors, sicklefish, butterflyfish, angelfish, parrotfish, mullets, batfish and rabbitfish were all caught during the hotter summer months between June-September. Closer examination of the occurrence of species (Table 22) revealed a similar distinctive pattern of occurrence of particular taxa. Larger amounts of fish considered to be of lower economic market value (like sicklefish, butterflyfish, angelfish and batfish) tended to be caught during the hot summer months when other more profitable taxa were less accessible. Most narrow-barred spanish mackerel were again caught between February to April, as opposed to during December at Ras al-Khaimah within the Gulf.

Between June 1978 until May 1979 a further survey was carried out of the landing data from Kalba (Ali et al. 1980). Jacks and Trevallies formed the greatest percentage of the total weight of the annual catch (24%), followed by emperors (11%), snappers and tuna/mackerel (10%), groupers and grunts (6%), goatfish and barracuda (4%), cobia, seabream and threadfin/monocle bream (2%). All other families formed 1% or less of the total annual catch. The best fishing month in terms of greatest weight of catch landed was October, followed by September and April. The overall pattern was also more dispersed like Khor Fakkan suggesting less marked seasonality of occurrence of taxa (Table 23). Moderate to large quantities of requiem shark, sea catfish, flatheads, cobia, jacks/trevallies, dolphinfish, snappers, seabream, mullets, goatfish, butterflyfish, sicklefish, angelfish, parrotfish, batfish and rabbitfish were all caught during the hotter summer months between June-September. Closer examination of the breakdown of the occurrence of particular species (Table 24) reveals that a number of carangid species like the yellowtail scad, malabar trevally, giant trevally, golden trevally and talang queenfish were all landed in significant quantities during the hottest months of July-August. Snappers also formed a significant component of the summer catch. Most narrow-barred spanish mackerel were again caught in the late spring between March to May.

3.7.4. United Arab Emirates – Biology of important fish

In 1981 the Fisheries Research Project of the Ministry of Agriculture and Fisheries initiated a study of the biology of some of the most important commercial demersal and pelagic fishes found in UAE waters (Ali et al. 1984). Fish were collected from various fish markets on both the east (Gulf of Oman) and west coast (Arabian Gulf) of the UAE. This study noted the total length, fork length, weight, sex, maturity stage, weight of gonad and stomach contents of each fish specimen examined. Twelve species were examined in this study.

Two species of sardinella (*Clupeidae*: *Sardinella* spp.) were commonly seen in UAE waters, the Indian oil sardine (*Sardinella longiceps*), and Sind sardinella (*S.sindensis*). The Indian oil sardine was not found during the months of May, June, August and September. The spawning season for this species was identified as being sometime after April, probably during May or June. A second spawning season was indicated in November by the presence of mature ripe (spawning) specimens. The largest specimens (average total length and body weight) were recorded between February, March and April, the smallest being noted in January (Ali et al. 1984: 20-22). The Sind sardinella was not seen in UAE markets between July to November. No mature nearly ripe fish were recorded throughout the year so it seems likely that this species migrates from the fishing areas to spawn elsewhere. This may take place sometime between July and November (Ali et al 1984: 23-25). Largest specimens were seen in April and the smallest in December.

Jacks/trevallies (*Carangidae*) were noted as being one of the most important commercial fish families in UAE waters. Common genera represented included: *Alectis*, *Alepes*, *Carangoides*, *Caranx*, *Decapterus*, *Elagatis*, *Gnathanodon*, *Megalaspis*, *Scomberoides*, *Selar*, *Selaroides*, and *Seriolina*. Three species of *Scomberoides* were seen in UAE waters: the Talang queenfish (*Scomberoides commersonianus*), the doublespotted queenfish (*S.lysan*), and the needlescale queenfish (*S.tol*). The Talang and needlescale queenfish were reported as being very common in UAE waters, whereas the doublespotted queenfish was only occasionally recorded. The main spawning season of the needlescale queenfish (*Scomberoides tol*) was noted as being during May-June, a second spawning season occurring during October. Smallest specimens were obtained during August, larger individuals being collected during May, June and October. This species is a pelagic fish which occurs in schools in surface waters where it mainly feeds on other smaller pelagic fish. Analysis of stomach contents identified the remains of sardines and other small fish.

The blacktip mojarra (*Gerres oyena*) was the commonest species of mojarra seen in UAE waters. It was seen in UAE markets throughout the year. The spawning season for this species was identified as being between June to October. Largest specimens were collected during April, the smallest during August (Ali et al. 1984: 6-7)

The common genera of snappers (Lutjanidae) seen in UAE waters were *Lutjanus* and *Pinjalo*. The predominant species noted were malabar snapper (*Lutjanus malabaricus*), yellowlined snapper (*L.lutjanus*), John's snapper (*L.johnii*), fivestripe snapper (*L.quinquelineatus*), and Russell's snapper (*L.russelli*). Collection of a small number of fivestripe snappers tentatively suggested that the spawning season lay between April to June. Largest specimens were collected during April (Ali et al. 1984: 12-14).

The most abundant of the threadfin bream species noted in UAE waters was the delagoa threadfin bream (*Nemipterus bipunctatus*). It was seen in UAE markets throughout most of the year, except during February, June and September. The spawning season for this species was identified as being during April to May. Largest specimens were collected during May, and the smallest specimens during December (Ali et al. 1984: 9-10).

The redspot emperor (*Lethrinus lentjan*), along with the spangled emperor (*L.nebulosus*), were noted as being the most common emperor species seen in UAE waters. It was seen in UAE markets throughout the year. The redspot emperor was observed to have two spawning seasons during the year, the first main one between May and June and the second season in late September and early October. Largest specimens were collected during November and the smallest during July (Ali et al. 1984: 7-9).

The common genera of seabream (*Sparidae*) noted in UAE waters by the study were *Argyrops*, *Acanthopagrus* and *Rhabdosargus*. The king soldierbream (*Argyrops spinifer*) was not seen in catches throughout the year, none being recorded between June-November. The spawning season for this species was between March and April. Largest specimens were collected during December, the smallest specimens being recorded during May (Ali et al. 1984: 11-12).

Two of the common species of mullet seen in UAE catches were noted as being the largescale mullet (*Liza macrolepis*) and the bluespot mullet (*Valamugil seheli*). Schools of largescale mullet were reported as being often seen in the surface waters even though it is primarily a bottom feeder. It was seen in UAE markets throughout almost the entire year, except for during July. The spawning season for this species was identified as being during April to May. Largest specimens were collected during May, the smallest during June (Ali et al. 1984: 14-16). The other common mullet species, the bluespot mullet, generally fetched higher prices in the markets. Too few specimens were collected to identify the precise spawning season or further information concerning the size variation or diet of this species (Ali et al. 1984: 16-17).

The commonly seen members of the tuna/mackerel (*Scombridae*) family in UAE waters are the Indian mackerel (*Rastrelliger kanagurta*), narrow-barred spanish mackerel (*Scomberomorus commerson*), kawakawa or eastern little tuna (*Euthynnus affinis*) and longtail tuna (*Thunnus tonggol*). The Indian mackerel (*Rastrelliger kanagurta*) was seen in UAE markets throughout the year, except for during June and August (Ali et al. 1984: 17-20). The spawning season for this species lay over an extended period between April to October. Smallest specimens were collected during September, the average total length being 20cm or more greater during the rest of the year.

The most common species of rabbitfish in inshore UAE waters was the pearlspotted rabbitfish (*Siganus canaliculatus*). It was seen in UAE markets throughout the year. The main spawning season for this species was between April and June, a second spawning season occurring in early August. Largest specimens were collected during May, and the smallest specimens were observed during July. Stomach contents suggested a diet predominantly based on seaweeds like *Halodule* spp., *Halophila* spp., *Ulothrix* spp., *Enteromorpha* spp. and *Cladophora* spp. (Ali et al. 1984: 2-5).

The study by Ali et al. (1984) concluded that the most of the species studied had spawning seasons between April-June, and that sea water temperature may be an important factor in determining the timing of this phenomenon. However, they noted that further studies were urgently required concerning the physiology of the fishes, age determination of the fishes by study of their otoliths and scales, as well as hydrographical and ecological studies of local conditions before firmer conclusions could be drawn.

3.8. Modern fishing methods utilised in the Gulf

Various methods are used to capture fish in the region at the present time (Table 25). The fisheries can broadly be divided into modern commercial fisheries, dhow-based fisheries, speed-boat based fisheries and recreational fishing.

Commercial or industrial fisheries take place using modern trawlers. These in particular target shrimp during the open season and finfish during the closed season. A variety of fish are caught including sharks and rays, seacatfish (*Ariidae*), lizardfish (*Synodontidae*), flatheads (*Platycephalidae*), groupers (*Serranidae*), jacks (*Carangidae*), ponyfish (*Leiognathidae*), snappers (*Lutjanidae*), threadfin bream (*Nemipteridae*), emperors (*Lethrinidae*), seabream (*Sparidae*), goatfish (*Mullidae*), turbots (*Psettodidae*), flounders (*Bothidae* and *Paralichthyidae*) and tonguesoles (*Cynoglossidae*). In actual fact within the Gulf the amount of trawling has been severely reduced in recent years by limiting the size of fleets and the length of the open season. The combination of overexploitation resulting from inadequate fisheries management and degradation of the environment is a major cause of the overall decline in fish and shrimp catches. This degradation includes the elimination of important nursery areas (especially for shrimp) by land reclamation and dredging in the coastal areas, destruction of feeding and breeding habitats by bottom trawling, and increased marine pollution by discharge of liquid and solid wastes into the marine environment (Chiffings 2000).

Dhow-based fisheries are usually either artisanal or small commercial operations. Traditional wooden dhows usually about 10-20m in length are powered by 150-300 horsepower inboard diesel engines. Dhows typically fish with baited basket traps (known locally as "gargoor"), trawls, drift nets, hook and line and trolling lines.

Small shore-based fisheries usually use fibreglass speedboats with one or two 30-60 horsepower outboard motors. Fishing is mostly carried out with gargoor and hook and line along rocky shores and jetties, or more often along beaches or intertidal areas using beach seines, gill nets and barrier traps (known locally as "hadrah").

Recreational fishing is a rapidly growing phenomenon in the region. This is largely carried out by small motor boats based from the shore. Hook and line is the predominant method used although gargoors may be used on extended fishing trips.

3.9. Traditional fishing techniques in the Gulf

The most effective way to comprehend the ancient fisheries of the Gulf is to consider the traditional artisanal fishing methods which are still in use around much of the Gulf today. Much of the technology adopted has been in use in a similar form for at least hundreds of years, if not for even longer periods back into the past. Although fibreglass boats and outboard motors have been introduced since the early 1970s, the major technologies used like basket traps, barrier traps, handlines, beach seines and casting nets are much the same. It is important that this information is recorded as many of these traditional methods are fast disappearing with the advent of new technology and the changes taking place within society in the new oil-rich states of the Gulf. In the United Arab Emirates the vast majority of the fishermen are expatriate workers originating from the south-Asian subcontinent, usually from Kerala in India or Bangladesh. Locals are involved to the extent that they own the boats, and employ fishermen, but comparatively few actually get involved in day to day fishing activities, even though the law actually requires a local to be present on each fishing boat which goes out. As a result of this there has been a gradual decline in the participation of the younger generation of Emiratis in fishing activities, and also a loss of traditional knowledge. The author was fortunate enough to be able to talk with a number of local old fishermen, several eminent local fisheries biologists as well as a number of Indian fishermen on the islands of Sir Bani Yas and Merawah to derive some of the information presented in this section. These people included: Darwish al-Rumaithi (Merawah, western Abu Dhabi region), Mr. Asad Shahin (Dalma Co-operative, western Abu Dhabi region), Dr. Saif al-Ghais (Chairman, Environmental Research and Wildlife Environmental Agency – ERWDA, Abu Dhabi), Thabit Zahran Salim Al-Abdessalaam, Mohamed al-Rumaithi, and John Hoolihan (Marine Environmental Research Center, ERWDA), Mohamed Abdel Rahim Hassan (Director), Ahmed Abdul Rehman Al-Janahi (Head of the Fishery Extension Section) and Mohamed Al Zarouni (Researcher, at the Ministry of Agriculture and Fisheries Marine Resources Research Centre, Umm al-Qaiwain). Additional local information was provided by regular fishing trips made by the author with an Indian fishermen (Mr. Ashraf) on Sir Bani Yas island, where fishing is largely carried out by handlines from the shore. A trip was also made with a couple of Indian fishermen on Merawah island using a fibreglass speed boat with an outboard motor, where drifting gill nets were set overnight. Further opportunities to examine traditional fishtraps were permitted during the course of fieldwork carried out on Dalma, Sir Bani Yas and Merawah islands in the western Abu Dhabi region.

Regular visits to the fish markets on Dalma island as well as both markets in Ras al-Khaimah in the northern Emirates also enabled further information to be gathered.

The traditional fishing methods utilised in the UAE are summarised in Table 26. Basket traps, known locally as "gargoor" (larger ones are sometimes referred to as "doubaya"), are one of the common methods utilised. Traditionally these were cylindrical in shape with a cone-like entrance, the whole trap being made from interwoven palm fronds. An example of one of these can be seen in Al Ain museum in the UAE (Figure 11). Nowadays, following the import of steel wire usually from the Far East, these tend to be made as dome-shaped traps with a base diameter of between 1-2 metres supported by reinforced steel bars and a funnel like entrance (Figure 12). The traps are generally laid in the sub-littoral sand-mud flats at depths ranging between 4-12m. Polystyrene or plastic marker buoys are used to mark their location. These traps are usually set in the afternoon and the retrieval of fish is carried out the following morning. A variety of baits are used inside the traps including green algae (*Enteromorpha*), ground dry fish, dead fish, bread and shrimp. Large gargoors target species like groupers (*Epinephelus* spp.), emperors (*Lethrinus* spp.) and grunts (*Haemulidae*). Other important varieties of fish caught in gargoors include various jacks (*Carangidae*) including the blackbanded trevally (*Seriolina nigrofasciata*), snappers (*Lutjanidae*), seabream (*Sparidae*), parrotfish (*Scaridae*) and rabbitfish (*Siganidae*).

One of the other traditional fishing methods used in the shallow waters of the Gulf are tidal barrier traps, known locally as "haddrah" (or "al hadhra"). In Bahrain these are constructed over the course of one or two weeks by specialized fishermen called "Rassam" (Al-Baharna 1986: 18). Such traps are often shaped like an arrowhead in Bahrain, the trap being perpendicular to the shoreline with the pointed end facing out to sea. However, in the UAE a variety of shapes exist including mainly circular, pentagonal, square, "question mark"-shaped, or "banjo"-shaped traps. Such traps were made traditionally by driving a row of palm fronds and wooden stakes into the mud-sand bottom supported by stones at their base. A frond fence was then placed between these stakes out towards the outer circular/pentagonal enclosure, which in turn surrounded an inner chamber. With the receding of the tide fish were thus channelled by the wings of the trap into first an outer, then an inner chamber. In the UAE these traps are traditionally used especially during the summer months to catch the blackspot snapper (*Lutjanus fulviflamma*). Other typical kinds of fish caught using haddrah include needlefish (*Belonidae*), jacks (*Carangidae*), seabream (*Sparidae*), mullets (*Mugilidae*), barracuda (*Sphyraenidae*) and rabbitfish (*Siganidae*).

Other bottom species may also be occasionally caught in these traps. The modern versions of the haddrah are usually made with steel or iron poles and wire mesh or nylon netting. An example of one of these can be seen in Figure 13.

Other variants of tidal barrier traps also exist in the UAE. One is a wide fence of nets linked by wooden posts called "sakkar". This may be stretched across narrow estuaries or gaps in lagoons. This is particularly used in the capture of mojarras (*Gerreidae*) and goldstriped seabream (*Rhabdosargus sarba*). Sometimes a second fence called "dafaf" is added behind the "sakkar", and this may catch fish like seabream (*Acanthopagrus* spp.) and flathead mullets (*Mugil cephalus*).

As traditional gargoor and haddrah were made entirely of organic materials we unfortunately have little chance of identifying them in the archaeological record. However, the stone footings supporting the fence-like structure perpendicular to the shoreline leading out towards the main enclosure may still survive. During April 1995 the author, along with Prof. Ernie Haerinck from the University of Ghent and Liz Shepherd from the Abu Dhabi Islands Archaeological Survey (ADIAS) team, visited the island of Dalma for several days as part of the ADIAS survey programme. Whilst travelling around the mid-western coast of the island, about a kilometre south of the municipal waste dump, a series of stone built fish traps were observed (Figures 14-15). However, these do not appear to be simply stone footings for where palm frond haddrahs originally stood. They have quite solid stone walls constructed from the local beach rock, known locally as "farush". As these are located in the present inter-tidal zone it is presumed that they are Late Islamic in date. Subsequent enquiries on the island regarding the antiquity of the traps came to no avail. A whole series of walls appeared to project out from the shore, some were perpendicular to the shoreline (Figure 15), whilst others formed diagonal or arc-like shapes suggesting that the whole of the local bay was enclosed (Figure 14, distance). Just below the line of the high tide was a large stone circular enclosure about 8m in diameter which had an opening on its seaward side (Figure 14, foreground). In April 2000 the author briefly visited the island of Ghagha in western Abu Dhabi and close to Qatari waters. Here a small bay was enclosed by a stone wall projecting in an arc to enclose the whole of the inlet. Other fish traps made completely of stone have also been observed on some of the other islands in the shallow waters of the westernmost Abu Dhabi region (Simon Aspinall and Peter Hellyer, pers. comm.). These sites are not generally well known in the region largely because they lie in relatively unpopulated remote areas. Modern coastal development including dredging activities and land reclamation has almost certainly destroyed many of these sites and it has been suggested that surviving examples should be preserved for posterity (Hellyer and Beech, forthcoming).

Gillnets, known locally as "liekh", are often set on the bottom. These catch a variety of fish including grunts (*Haemulidae*), seabream (*Sparidae*), emperors (*Lethrinidae*), goatfish (*Mullidae*), rabbitfish (*Siganidae*), pomfrets (*Stromateidae*), and others. A further type of gillnet is known as "hayal". These are special drifting gill nets which are normally used during the winter to capture in particular the narrow-barred Spanish mackerel (*Scomberomorus commerson*), which is abundant at that time. Two nets are used, one is movable whilst the other is fixed with weights. Such a method is also used to capture cobias (*Rachycentridae*), jacks (*Carangidae*), barracuda (*Sphyraenidae*) and tuna (*Scombridae*).

Two other types of fishing nets are used. Beach seines, known locally as "yaroof", can be up to 40m or more in length. One end of the seine is moved rapidly from the shore in a wide arc in an effort to surround fishes; both ends of the seine are then pulled to shore. Speedboats with outboard motors and even four wheel drive vehicles are used at the present day to pull these seine nets to the shore, but traditionally this was done by a large group of men. Some fishermen mending their beach seine nets in the northern Emirates are depicted in Figure 16. These nets are weighted down with stone net sinkers (Figure 17), some of which bear a strong resemblance to archaeological examples dating back as far as the 3rd millennium BC (Chapter 4.1.2.). Fishing using this method is especially good at catching mojarra (*Gerreidae*), flathead mullets (*Mugil cephalus*) and rabbitfish (*Siganidae*). Many other fishes can also be caught including small needlefish (*Belonidae*) and jacks (*Carangidae*). The other type of fishing net which is sometimes used is the casting net, known locally as "Salieya". This is only used at particular times of year when fish like the Indian oil sardinella (*Sardinella longiceps*) and flathead mullets (*Mugil cephalus*) may be abundant in shallow inshore waters. The fishermen wade into shallow waters and throw a bell-shaped fine net onto the surface of the water which has small weights around its base to make the net sink and surround the fish.

A method which resembles a sort of harpoon, known locally as "oumla", is sometimes used. A large wooden spear referred to as "al katra" with a sharp metal unit called "al jalala" is inserted into another metal unit called "al kaber". This latter section has a float attached to it. The "oumla" is particularly used for the spearing of large pelagic fish like tuna, narrow-barred Spanish mackerel and was even occasionally used on Cetaceans in the past.

All other traditional fishing methods utilised rely on hook and lines of one sort or another. In its most simple form, the hook and line method, known locally as "hadaq", is particularly used for the capture of groupers (*Serranidae*), cobias (*Rachycentridae*), jacks/trevallies (*Carangidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), and spanish mackerel (*Scombridae*: *Scomberomorus* spp.). Sometimes longlines, known locally as "manshalla", are used which may have 10-20 more smaller lines and hooks. These are reputed to be good for catching requiem sharks (*Carcharhinidae*) and groupers (*Epinephelus* spp.). Another local variant is "Shab", which is a nylon line with 4-8 shorter lines and hooks which have lures (small feathers or pieces of coloured material) fastened to them. This is apparently very good at catching blacktip trevally (*Caranx heberi*), golden trevally (*Gnathanodon speciosus*) and queenfish (*Scomberoides* spp.). The final method which is used from moving boats is a trolling line, known locally as "lafah". This is particularly used for the capture of larger fish like giant trevally (*Caranx ignobilis*), barracuda (*Sphyraena* spp.), narrow-barred Spanish mackerel (*Scomberomorus commerson*), tuna (mostly *Euthynnus affinis*/*Thunnus* spp.), and occasionally sailfish (*Istiophorus platypterus*).

3.10. Summary

The aim of this chapter is to review the modern and traditional fisheries of the Arabian Gulf and Gulf of Oman.

How many (and which) fish are present in the region?

The present day fish fauna of the Arabian Gulf was established by the penetration of species from the Indian Ocean through the Gulf of Oman and Straits of Hormuz. Comparatively little is still known about the Arabian Gulf marine fauna. There are a great number of misidentifications within the existing literature. The recent publication of Randall's "Coastal Fishes of Oman" (Randall 1995) along with the FAO Field Identification Guide by Carpenter et al. (1997) have fortunately summarised many of these and represent the most recent attempts to update the taxonomy. There is considerable regional variation in the numbers of fish taxa observed in different regions of the Gulf. Fewer species seem to be identified in the some of the western and southern areas of the Gulf (Coles and Tarr 1990; Smith et al. 1987; Dipper and Woodward 1989). The numbers of species recorded on various surveys vary from as little as 35 to 361 species.

What are the characteristics of modern fisheries data from each of the sub-regions throughout the area? Is there any indication of the marked seasonal occurrence of particular fishes in certain locations within the study area? Are certain fish associated with particular habitats within the study area?

There appears to be considerable variation in the numbers, diversity and composition of fish throughout the Gulf. This may be related to factors such as bottom topography and sediment type. Whereas the northern and eastern parts of the Gulf, as well as the entrance Hormuz area, are relatively rich in certain species, a lot less variety of fish are present in the south-west and southern shores of the Gulf. For example, certain families such as croakers (*Sciaenidae*) and soles (*Soleidae*) have more species in the NW Gulf than in the SE. Sheppard, Price, and Roberts (1992) have recognised that important ecological gradients or controls in species distribution and abundance have to be taken into consideration in understanding the biogeography of fishes in Arabia. One of the key problems is the lack of ecological data on fish habitat preferences. Preliminary work by Basson et al. (1977), McCain et al. (1984), Downing (1987), Smith et al. (1987) and Smith and Saleh (1987), all suggest that certain fish may be associated with particular habitats and that their occurrence may be highly seasonal. A close examination of fisheries landing data obtained from fisheries offices in the UAE, as well as from the compilation of data in a number of "grey literature" reports, demonstrates that fish landings are highly seasonal within the Gulf, but less so on the eastern coast of the UAE in the Gulf of Oman.

What modern fishing methods are used to catch the present day ichthyofauna? What traditional methods are utilised in the Arabian Gulf, and particularly along the coastline of the United Arab Emirates, to catch fish, and do particular methods target specific species?

Modern methods used to capture fish in the region include commercial or industrial fisheries using modern trawlers (particularly for shrimp and finfish), artisanal dhow-based fisheries, small shore-based fisheries using fibreglass speedboats and recreational fishing. A review of the modern and traditional methods used in artisanal fisheries highlights the technology which has been developed to target particular fish families and species. Basket traps ("gargoor") are frequently used in the artisanal fisheries to catch fish like groupers (*Epinephelus* spp.) and emperors (*Lethrinidae*). Tidal barrier traps ("haddrah") are typically used to catch fish like the blackspot snapper (*Lutjanus fulviflamma*) and seabream (*Sparidae*) during the hot summer months. Barrier traps placed across narrow estuaries or gaps in lagoons ("sakkar") are often used to catch mojarras (*Gerreidae*) and seabream (*Rhabdosargus* spp.). Other fishing methods include the use of gillnets, beach seines, casting nets, harpoons and various types of hook and line arrangements. Many of these target particular families or groups of species (section 3.9).

The following chapter will examine the possible evidence for the chronological development of fisheries in the Arabian Gulf and Gulf of Oman, based on past studies of zooarchaeological, archaeological and historical data.

CHAPTER 4

THE CHRONOLOGICAL DEVELOPMENT OF FISHERIES IN THE ARABIAN GULF AND GULF OF OMAN: PAST STUDIES

The goal of this chapter is to examine the chronological development of fisheries in the Arabian Gulf and Gulf of Oman, based on past studies of zooarchaeological, archaeological and historical data.

- Does change through time influence the composition of fish faunas in this region?
- What kinds of fishing equipment have been adopted through time?
- Does the adoption of new fishing technologies indicate a change in fishing strategies?
- Does documentary evidence provide any insight into the history of fish exploitation in this region?

After considering past zooarchaeological research on fish bone assemblages in the region (section 4.1), the archaeological evidence for fishing technology is considered (section 4.2). Various historical sources are then evaluated (section 4.3).

4.1. Past zooarchaeological research

All the existing published records relating to fish bone assemblages within the Arabian Gulf and Gulf of Oman are summarised in Tables 27-31. Sites where quantitative information was available are also summarised in Figure 18. One of the problems in reviewing the already published studies concerning fish assemblages in the region is that the precise methods for the recovery of material are not always provided. The lack or absence of sieving on many sites will dramatically affect the occurrence and abundance of smaller fish taxa, biasing the overall picture. Details of the recovery methods utilised at each of the already published studies are included in Tables 27-31.

This present study of new zooarchaeological data from 23 sites located throughout the Arabian Gulf and Gulf of Oman (Chapter 5) aims to re-assess the overall regional model of fisheries exploitation derived from the following already published data (sections 4.1.1 – 4.1.5), in the light of this new more rigorously collected material.

4.1.1. 5-4th millennium BC

The fish bones from Abu Khamis (figure 9, no. 3), located on the Saudi Arabian Gulf coast, have not yet been studied. This material was collected in the late 1960s by Abdullah Masry during the course of his study of inter-regional interactions in NE Arabia (Masry 1974, 1997). Masry noted that fish bones formed 85% of the total weight of bone from the site. Melinda Zeder examined the small collection of mammalian remains from the site and identified the presence of gazelle, sheep/goat (all those bones which could be identified as being sheep or goat were goat), carnivore, equid and cattle or equid (Zeder 1974). A preliminary examination of the fish assemblage was made by the author during a research visit made in early October 1999 to the Natural History Museum at the Smithsonian Institution in Washington D.C., where the collection is housed. This revealed that shark/ray/skates (*Chondrichthyes*), jacks/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) were all common, with groupers (*Serranidae*) and seabream (*Sparidae*) also being present within the assemblage. The method of recovery of this material is not clear although it seems likely that a combination of both hand retrieval and some sieving was carried out.

The largest collection dating to this period so far examined is the recently published fauna from site J19 at Al Markh in Bahrain (von den Driesch and Manhart 2000). This site is located on the south-west coast of Bahrain (Figure 9, no. 7). The recovery of material on the excavation was carried out initially using a 4mm sieve. Some of the deposits in the lower levels at site J19 were recovered by wet sieving using a plastic fly-screen mesh of about 1.5mm. The resulting fractions were subsequently divided into >5mm, 1.5-5mm and <1.5 mm. Only the >5mm bones were brought back to Germany for subsequent analysis, and a very small proportion of the <5mm bones. The Al Markh assemblage was dominated by seabream (*Sparidae*), which formed 83% of all those bones identifiable to family. The most common genera represented amongst these remains were goldstriped/haffara seabream (*Rhabdosargus*), closely followed by *Acanthopagrus*. Other genera represented in smaller quantities included porgy (*Diplodus* spp.), king soldierbream (*Argyrops spinifer*) and karanteen seabream (*Crenidens crenidens*). Significant quantities of Bloch's gizzard shad (*Nematolosa nasus*) were also observed. Other fish represented in decreasing quantities included groupers (*Serranidae*, mostly *Epinephelus* spp.), emperors (*Lethrinidae*), mojarras (*Gerreidae*) and ponyfish (*Leiognathidae*), jacks/trevallies (*Carangidae*), including the genera *Carangoides*, *Gnathanodon* and *Scomberoides*, barracuda (*Sphyraenidae*), hammerhead shark (*Sphyrnidae*), silversides (*Atherinidae*), snappers (*Lutjanidae*), mullets (*Mugilidae*), requiem sharks (*Carcharhinidae*), sawfish (*Pristidae*), rabbitfish (*Siganidae*), grunts (*Haemulidae*), sea catfish (*Ariidae*), flatheads (*Platycephalidae*), giant guitarfish (*Rhynchobatus djeddensis*), stingray (*Dasyatidae*), sardines (*Sardinella* spp.), kawakawa/eastern little tuna (*Euthynnus affinis*) and needlefish (*Belonidae*). Most of the fish remains came from the lower levels at J19. The upper layers appeared to contain slightly different proportions of the commonly occurring fishes. Groupers (*Serranidae*), and also possibly jacks/trevallies (*Carangidae*) and emperors (*Lethrinidae*), all appeared to be more common than in the lower layers, although seabream (*Sparidae*) were still evidently being caught. However, such differences may be due to poor sample size in the upper layers as well as taphonomic factors.

Several archaeological sites in Qatar have been investigated dating to the 5-4th millennium BC. One of the sites investigated on the west coast of Qatar is Ras Abaruk (Figure 9, no.8). A survey carried out by G.H. Smith, as part of wider survey of archaeological sites in Qatar (de Cardi 1973), discovered a so-called "fish processing complex" at a locality named site 4. The site consisted of a sunken hearth with clear evidence of burning, with associated fish remains. Fish bones were described as being present but unfortunately no analysis of these remains was included in the report (Smith 1978: 80-106). Two sites have been examined at Khor located on the north-east coast of Qatar (Figure 9, no.9). At Khor FB it is reported that both silversides (*Atherinidae*) and seabream (*Sparidae*) were represented. The remains consisted almost exclusively of otoliths from these species, with very few vertebrae being noted (Desse 1988). A preliminary study of these otoliths revealed no obvious seasonal preference, although it is suggested that more fishing may have been carried out during the winter period (Desse 1988: 79). At site Khor P notable quantities of seabream and silverside otoliths were also recovered, as well as numerous loose teeth from seabream, some otoliths from jacks/trevallies (*Carangidae*) and groupers (*Serranidae*), and a few fish vertebrae, including a single shark/ray/skate vertebra (Desse 1988: 161-2). On the south-east coast of Qatar a further site was investigated by the same team of French archaeologists who worked at Khor. This was the site of Shagra (Figure 9, no.10). Here, the small assemblage included predominantly vertebrae from small shark/ray/skates (*Chondrichthyes*), as well as some cranial fragments and otoliths from groupers (*Serranidae*) and seabream (*Sparidae*). It was reported that analysis of the growth rings of the fish vertebrae from Shagra showed that the fish were caught throughout the year and not during any particular season (Desse 1988: 226). Although it is noted that systematic sieving was carried out across the whole site at Khor FB, Khor P and Shagra, the precise mesh size is not stated. It seems likely from the finds that a fine mesh screen ca 3-4mm may have been utilised.

At site 69 within the Umm al-Qaiwain lagoon area of the UAE (Figure 10, no.20 and Figure 102), it is reported that the remains consisted of small vertebrae and otoliths from emperors (*Lethrinidae*) and seabream (Uerpmann and Uerpmann 1996: 134). At site 69 the deposits were sieved using a fine mesh screen (?ca. 3-4mm). On the nearby site of Akab island (Figure 102), it was noted that fish remains were also common at the specialised dugong butchery site (Chapter 2.2.4).

In the Gulf of Oman, pelagic tuna/mackerel (*Scombridae*) were numerous at the 4th millennium BC site of RH5 at Qurum (Biagi et al. 1984), indicating that some fishing was carried out in the open seas off the Omani coast.

In summary, many of the early Arabian Gulf sites appear to be characterised by the capture of small fishes like sea breams and silversides, suggesting that fishing was mostly conducted inshore in sheltered coastal waters. Little fishing appears to have been conducted on reefs (e.g. the complete absence of parrotfish and relatively low quantities of groupers). There is also only extremely sparse evidence for a fishery based on larger pelagic fish like some of the jack/trevallies (*Carangidae*) and tuna and mackerel (*Scombridae*). There is a complete absence of *Rastrelliger kanagurta, Scomberomorus* spp. and *Thunnus* spp. The only two sites where any scombrids were noted as being present were Abu Khamis and Al Markh. Whilst the bones from Abu Khamis are not yet studied, the remains from Al Markh consisted of just two vertebrae from a kawakawa/little eastern tuna (*Euthynnus affinis*). The fact that systematic dry sieving was carried out at Al Markh, as well as wet sieving of some of the lower levels, undoubtedly accounted for the fact that a greater list of taxa, and particularly of smaller fish, was obtained here than at the other sites. The evidence from the Gulf of Oman suggests a different picture in that fishing in offshore waters appears to have been practised already in the 4th millennium BC. The distribution of shell fish hooks (section 4.2.2.) also indicates that offshore fishing for larger fish was clearly carried out on the Omani coast. It is curious that no shell hooks have been published to date from the Arabian Gulf. Perhaps this suggests that less deep water fishing was carried out in the Gulf? Or, that such fishing was so highly seasonal that there was a lesser chance of such objects being lost or discarded on archaeological sites.

4.1.2. 3rd-2nd millennium BC

The only locality investigated belonging to this period in the northern Gulf is a site located on Failaka island, off the coast of Kuwait (Figure 9, no.2). Between 1985-6 a Dilmun period site known as "F6" was excavated there by Yves Calvet and Marielle Pic (Calvet and Gachet 1990). The majority of the assemblage here consisted of groupers (*Serranidae*), followed by jacks/trevallies (*Carangidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*), emperors (*Lethrinidae*), sea catfish (*Ariidae*), wolf herrings (*Chirocentridae*), grunts (*Haemulidae*), and angelfish (*Pomacanthidae*) (Desse and Desse-Berset 1990). The groupers were all identified as being *Epinephelus* spp. Golden trevally (*Gnathanodon speciosus*) was the most common carangid present. Seabream genera represented included *Acanthopagrus* spp. and the king soldierbream (*Argyrops spinifer*). Recovery of material was predominantly carried out by hand with some sieving being undertaken to monitor the presence of smaller fish (Desse and Desse-Berset 1990: 59). Unfortunately the mesh size is not stated although judging from the finds it may have been in the range 2-4mm.

In Bahrain, two sites have been studied with fish assemblages dating to this period. At the Dilmun temple at Saar (Figure 9, no.6), the assemblage was dominated by emperors (*Lethrinidae*), followed by seabream (*Sparidae*) and barracuda (*Sphyraenidae*) (Moon and Irving 1997). Moderate quantities of groupers (*Serranidae*) were followed by smaller quantities of jacks/trevallies (*Carangidae*), snappers (*Lutjanidae*), tuna/mackerel (*Scombridae*), goatfish (*Mullidae*), rabbitfish (*Siganidae*), grunts (*Haemulidae*), needlefish (*Belonidae*), flatheads (*Platycephalidae*), cobia (*Rachycentridae*) and angelfish (*Pomacanthidae*). All of the contexts producing animal remains at the Saar temple were dry sieved using a 1mm mesh.

At site 520 at the nearby site of Qalat al-Bahrain on the northern coast of Bahrain (Figure 9, no.5), the assemblage was dominated by groupers (*Serranidae*), followed by emperors (*Lethrinidae*), seabream (*Sparidae*), and jacks/trevallies (*Carangidae*) (Van Neer and Uerpmann 1994). Smaller quantities of guitarfish (*Rhinobatidae/Rhynchobatidae*), followed by requiem shark (*Carcharhinidae*), sea catfish (*Ariidae*), tuna/mackerel (*Scombridae*), hammerhead shark (*Sphyrnidae*), barracuda (*Sphyraenidae*) and sawfish (*Pristidae*) were also noted. The most common carangid genera present were the golden trevally (*Gnathanodon speciosus*) and members of the genus, *Carangoides* spp., followed by queenfish (*Scomberoides* spp.). Amongst the seabream, king soldierbream (*Argyrops spinifer*) were common, followed by goldstriped/haffara seabream (*Rhabdosargus* spp.) and members of the genus *Acanthopagrus* spp. Scombrids only formed less than 1% of the total identified assemblage but both the longtail tuna (*Thunnus* spp.) and kawakawa/little eastern tuna (*Euthynnus affinis*) were represented. All the fish bones from Qalat al-Bahrain came from levels which were not sieved, and this was reflected in the low proportion of unidentified remains (Van Neer and Uerpmann 1994: 445). The fact that no sieving was carried out for the retrieval of the fish assemblage may partly have exaggerated the amounts of medium to large-sized fish like groupers, emperors and jacks/trevallies, and have underestimated the quantities of smaller fish like seabream, and other taxa not represented at the site (e.g. *Clupeidae, Belonidae, Gerreidae, Leiognathidae*, etc.).

In the UAE it is reported that fish remains were collected during the Danish excavations on Umm an-Nar island (Chapter 2.2.4). Unfortunately no detailed analysis has been carried out of these remains although it is noted that the fish exploited were "mostly large", and that the remains included shark, sawfish and stingray (Hoch 1979). The fact that these remains are described as being "mostly large" may demonstrate that the observation was based upon hand collected material, as no specific mention is made of retrieval methods.

Elsewhere in the UAE, only two localities have been studied in detail dating to this particular period. These are the settlement sites of Tell Abraq on the border of Sharjah and Umm al-Qaiwain emirate (Figure 9, no.14; Figure 102) and Shimal in Ras al-Khaimah emirate (Figure 9, no.19; Figure 109), both sites being located in the northern Emirates. At Tell Abraq the study of the fish bones from the site has not yet been completed but preliminary information indicates that groupers (*Serranidae*), jacks/trevallies (*Carangidae*) and barracuda (*Sphyraenidae*) were all frequent within the assemblage (Potts 2000; Margarethe Uerpmann, pers. comm.). The presence of the following other families was also noted: requiem sharks (Carcharhinidae), hammerhead sharks (*Sphyrnidae*), sawfish (*Pristidae*), stingrays (*Dasyatidae*), sea catfish (*Ariidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), mullet (*Mugilidae*), tuna/mackerel (*Scombridae*), spadefish (*Ephippidae*) and rabbitfish (*Siganidae*). The method of recovery of material during the Tell Abraq excavation was a combination of hand recovery with some dry sieving being carried out (Potts 2000: 60-61). Unfortunately no precise information is yet available, although the usual type of dry sieves used at Tell

Abraq during some of the fieldwork seasons had a mesh size of about 5mm (Christian Velde, pers. comm.).

At the multi-period site of Shimal in Ras al-Khaimah emirate, a settlement has been excavated dating from the Umm an-Nar to Iron Age periods, ca. 2300-800 BC (Vogt and Franke-Vogt 1987). A total of 27 families including more than 46 fish species were identified even though all the bones were recovered by hand and no sieving was carried out (von den Driesch 1994). The assemblage was dominated by jacks/trevallies (*Carangidae*), followed by tuna/mackerel (*Scombridae*), seabream (*Sparidae*), mullet (*Mugilidae*) and sea catfish (*Ariidae*). Smaller quantities of barracuda (*Sphyraenidae*), followed by groupers (*Serranidae*), stingray (*Dasyatidae*), emperors (*Lethrinidae*), spadefish (*Ephippidae*), requiem shark (*Carcharhinidae*), hammerhead shark (*Sphyrnidae*), tenpounders (*Elopidae*), rabbitfish (*Siganidae*), needlefish (*Belonidae*), flatheads (*Platycephalidae*), guitarfish (*Rhinobatidae/ Rhynchobatidae*), snapper (*Lutjanidae*), milkfish (*Chanidae*), cobia (*Rachycentridae*), remoras (*Echeneidae*), grunts (*Haemulidae*), terapon (*Teraponidae*), houndshark (*Triakidae*), sawfish (*Pristidae*) and wrasse (*Labridae*) were also present. The most common genera amongst the carangids was *Scomberoides*, followed by *Caranx*, *Carangoides* and the golden trevally (*Gnathanodon speciosus*). Goldstriped/Haffara seabream (*Rhabdosargus* sp.) was the commonest type of seabream, followed by Acanthopagrus then the king soldierbream (*Argyrops spinifer*). The majority of the scombrid remains belonged to the longtail tuna (*Thunnus* sp.). Kawakawa/little eastern tuna (*Euthynnus affinis*) was represented in much smaller quantities and just a few specimens of Indian mackerel (*Rastrelliger kanagurta*) were also identified. Unfortunately in this publication a complete breakdown of which particular species occurred in each of the four site phases was not given, only combined percentages for the major families being presented in the form of a histogram (von den Driesch 1994: 79, Diagramm 2). This suggested that during the Umm an-Nar period (phase 1, ca. 2300-2000 BC) the assemblage was dominated by jacks/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*). During the subsequent Wadi Suq period (phase 2, 1900-1600 BC), there were far less jacks/trevallies and tuna/mackerel, seabream (*Sparidae*) dominating these levels. During the following Late Bronze age (phase 3, ca 1600-1300 BC) and Iron age periods (phase 4, 1200-800 BC) the relative amounts of seabream decreased again as jack/trevallies followed by tuna/mackerel re-emerged as the dominant families represented. It was suggested that this may represent an impoverishment of the settlement during the Wadi Suq period when fishing strategies concentrated on shallow inshore species like seabream rather than on deeper water pelagics. This should be taken with a "pinch of salt" though, as the fish remains from the site were recovered entirely by hand with no systematic sieving being carried out. This means that comparisons between phases may simply reflect differential recovery and preservation in the deposits.

Outside the Gulf, two localities have been investigated on the coast of Oman. At the site of HD1 at Ra's al-Hadd on the coast of Oman, groupers (*Serranidae*), jacks/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) predominated (Cartwright 1994; 1998). The fish assemblage at HD1 also included requiem sharks (*Carcharhinidae*), herrings/sardines/shads (*Clupeidae*), milkfish (*Chanidae*), sea catfish (*Ariidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), breams (*Nemipteridae*), emperors (*Lethrinidae*), seabream (*Sparidae*) and barracuda (*Sphyraenidae*) (Caroline Cartwright, pers.comm.). At HD1 a combination of hand recovery and dry sieving was carried out. Unfortunately no further details are yet available. The fact that relatively few small-sized families of fish were present at HD1 (i.e. only breams and seabream) perhaps indicates that hand recovery accounted for a good proportion of the assemblage. It seems strange that at the location of Ras al-Hadd, close to the well-known upwelling along the Gulf of Oman, that a large list of fish taxa has not so far been made from this site. This may well emerge with the future publication of the site. Certainly large quantities of small seasonal pelagics like sardines are caught along the modern coast of Oman close to this area. The absence of such smaller fish may be an effect of the recovery procedures used on the excavation.

The fish bones from Ra's al-Jinz (RJ-2) are currently under study by Nathalie and Jean Desse, who have noted that the main emphasis was on large species like yellowfin tuna (Cleuziou and Tosi 2000: 42). Net sinkers found at the site were typical of those found in Early Bronze age sites in the region (section 4.2.1). These were spherical or oval with a round section, and usually made out of the local limestone, with a deep grove made by pecking around their waistline (Clueuziou and Tosi 2000: 41). Some small net weights were also recorded. Copper fish hooks were all simple shaped hooks and varied in size from 2-10cm. It is suggested that fishing at RJ-2 was not merely a subsistence activity but rather a large-scale operation for an exchange economy (Cleuziou and Tosi 2000: 42).

In summary, a wider range of fish were noted on 3rd-2nd millennum BC sites than at the earlier period sites. Fishing strategies concentrated not only on shallow inshore coastal waters but also on reef areas as well as deeper offshore waters. Larger fish such as carangids and scombrids were noted in greater quantities than at the earlier sites. This was particularly the case with the Shimal settlement located in the northern Emirates, and at Ra's al-Jinz (RJ-2) and Ra's al-Hadd (HD1) on the Omani coast. The fact that no sieving was carried out at Shimal did not deter from the fact that this site produced the biggest list of taxa from any sites in the region, even including those sites where sieving was carried out. This may indicate the apparent richness of the deeper waters close to the entrance of the Gulf and Straits of Hormuz. This emphasis on larger fish like carangids and scombrids should be read with some caution though, as the lack of sieving may have exaggerated the presence of such taxa to the detriment of smaller important species like seabream.

4.1.3. Iron age, Hellenistic and Pre-Islamic periods

Few Iron age sites have been investigated to date with fish assemblages. At the aforementioned settlement site at Shimal, Iron age levels (phase 4, 1200-800 BC) were dominated by jacks/trevallies (*Carangidae*) with moderate quantities of tuna/mackerel (*Scombridae*), sea catfish (*Ariidae*), seabream (*Sparidae*) and mullet (*Mugilidae*), as well as smaller amounts of other species (von den Driesch 1994: 79, Diagramm 2). The fish bones from Tell Abraq are still under study by Margarethe Uerpmann and the results are awaited with interest. Preliminary information suggests that fishing there concentrated largely on local inshore and lagoon species (Margarethe Uerpmann, pers. comm.). The recovery methods utilised at both these sites are mentioned above in the preceding section.

Concerning Hellenistic and Late pre-Islamic period sites, three sites have been investigated to date. One of these, site F5, is located in the northern Gulf on Failaka island, off the coast of Kuwait (Figure 9, no.2). Here the assemblage was dominated by the remains of groupers (*Serranidae*), followed by jacks/trevallies (*Carangidae*), drums/croakers (*Sciaenidae*), seabream (*Sparidae*), grunts (*Haemulidae*), sea catfish (*Ariidae*), emperors (*Lethrinidae*), snappers (*Lutjanidae*), parrotfish (*Scaridae*) and barracuda (*Sphyraenidae*) (Desse and Desse-Berset 1990). Commonest genera amongst the carangids were *Caranx* and *Scomberoides*. Most of the grunts belonged to the genus *Pomadasys*. Members of the drum/croaker (*Sciaenidae*) family mostly belonged to the genus *Argyrosomus*. The bones discussed in the published report all represent hand collected material. Although it is mentioned that some test sieving was carried out during the last excavation season to collect some information on the presence and proportion of smaller sized species, less well preserved material, and otoliths, no further details concerning the results of this work are presented (Desse and Desse-Berset 1990: 59). This means that the importance of large fish like groupers and jacks/trevallies may very well be exaggerated. The only type of small fish represented at F5 were seabream.

A preliminary report has been published on the fish fauna from the site of Ed-Dur, located in Umm al-Qaiwain emirate in the UAE (Figure 9, no.15; Figure 102). The site is a vast 1st-4th century AD settlement located east of the Umm al-Qaiwain lagoon, which appears to have functioned as an important trading harbour as well as a focus for settlement and religious activities. Here it was noted that seabream (*Sparidae*) and tuna/mackerel (*Scombridae*) were "very frequent" (Van Neer and Gautier 1993). Groupers (*Serranidae*), jack/trevallies (*Carangidae*) and mullets (*Mugilidae*) were all described as being "frequent". Requiem sharks (Carcharhinidae), sawfish (Pristidae), stingrays (*Dasyatidae*), milkfish (*Chanidae*), sea catfish (*Ariidae*), barracuda (*Sphyraenidae*) and rabbitfish (*Siganidae*) were all described as being "rare". Hammerhead sharks (*Sphyrnidae*), herrings/sardines/shads (*Clupeidae*), needlefish (*Belonidae*), flatheads (*Platycephalidae*), snappers (*Lutjanidae*), mojarras (*Gerreidae*), grunts (*Haemulidae*), parrotfish (*Scaridae*), spadefish (*Ephippidae*), and puffers (*Tetraodontidae*) were all described as being "very rare". Most frequent genera amongst the carangids were *Carangoides* and the golden trevally (*Gnathodon speciosus*). Goldstriped/Haffara seabream (*Rhabdosargus* sp.) was the most common type of seabream, followed by king soldierbream (*Argyrops spinifer*) and *Acanthopagrus* spp. Both the kawakawa/eastern little tuna (*Euthynnus affinis*) and longtail tuna (*Thunnus* spp.) were reported to be "very frequent". A single pharyngeal bone from a freshwater cyprinid, *Barbus*, was also noted which is likely to be a foreign import as cyprinids of this genus do not occur on the Arabian peninsula (Van Neer and Gautier 1993: 113). No mention is made in this publication of the method of retrieval used on this particular excavation for the systematic recovery of all the faunal remains. However, it is mentioned that "anchovies and sardines were only represented by a few vertebrae from a context that was screened through a fine mesh" and that "some vertebrae and jaw fragments of small lizards and snakes were found in a well which was systematically sieved" (op. cit.). This indicates that some samples collected at the site were fine sieved. Although if sieving using a standard sized mesh was not used across the remainder of the site, then this may have partly exaggerated the presence of the large fish like groupers, jacks/trevallies and tuna, and have underestimated the proportion of smaller fish. This combination of variable recovery plus the low chances of small fragile fish bones surviving in the deposits may further account for their relative absence.

Another site which is broadly contemporary with Ed-Dur is the inland site of Mleiha, located in Sharjah emirate in the UAE (Figure 9, no.17). The remains of a 3rd-4th century AD fort with associated buildings have been excavated here. Fish bones were reported from both the fort (area CW) as well as from adjacent houses (area DA). The assemblage was dominated by the remains of tuna, in particular by kawakawa/little eastern tuna (*Euthynnus affinis*), with smaller amounts of longtail tuna (*Thunnus* sp.). The bones from *Euthynnus affinis* came from individuals between 40-70cm standard length, the majority being between 40-60cm in size. Other fish represented in small quantities included goldstriped/haffara seabream (Rhabdosargus sp.), jacks/trevallies (*Carangidae*), including the genus *Carangoides*, mullets (*Mugilidae*) and requiem shark (*Carcarhinidae*) (Mashkour and Van Neer 1999). Mleiha is located at least ca. 50km from the east coast and 80km from the west coasts of the UAE, so all these fish remains must represent deliberate imports to the site. The method of recovery used to collect the fish remains at Mleiha is unfortunately not mentioned in the publication, although it is stated that...

"a preferential destruction of more fragile bones from other species cannot explain the predominance of tuna. In fact the state of preservation of the bones was more or less identical in all the studied contexts. If one accepts equally that the collection methods have been constant in all the different excavation areas, then the predominance of tuna in the final phase of occupation at Mleiha may represent an economic phenomenon" (Mashkour and Van Neer 1999: 124)

In summary, during the Iron age the fishing of larger fish like carangids and scombrids in deeper offshore waters continued (e.g. Shimal) but clearly inshore coastal and lagoon areas were also regularly exploited (e.g. Tell Abraq). During the Hellenistic period in the northern Gulf, fishing clearly focused on reef areas around Failaka island, as well as on shallow inshore areas. The presence of drums/croakers like the genus *Argyrosomus* suggests that some of these areas may have included mud bottoms and estuaries. At 1st-4th century AD Ed-Dur, it is clear that fishing took place both within the neighbouring lagoon as well as regularly in deeper waters beyond the local lagoon. The large proportion of species like tuna, as well as the presence of large sizes of demersal fish like jacks/trevallies (*Carangidae*) and emperors (*Lethrinidae*), indicates that fishing was also carried out in the open sea. The fish assemblage from 3rd-4th century AD Mleiha demonstrates that some of these fish were already being traded to sites within the interior of SE Arabia by this time. Variable recovery methods and the differential survival of smaller fish remains should not be forgotten though, which may partly account for some of the apparent trend towards larger fish at sites like Ed-Dur and Shimal.

4.1.4. Sasanian, Late Pre-Islamic and Early Islamic periods

Only two sites have been investigated in the Gulf with fish assemblages dating from the Sasanian to Early Islamic periods. These are the Great Mosque at the port of Siraf on the Iranian Gulf coast (Figure 9, no.4) and Jazirat al-Hulaylah, located in Ras al-Khaimah emirate in the UAE (Figure 9, no. 20; Figure 109).

During the Sasanian/Early Islamic period levels at Siraf (phase 1A, 4-5th c. AD), the assemblage was dominated by seabream (*Sparidae*), followed by jack/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) (Badstöber 2000). Grunts (*Haemulidae*), groupers (*Serranidae*) and emperors (*Lethrinidae*) occurred in moderate quantities, followed by smaller amounts of sea catfish (*Ariidae*), snappers (*Lutjanidae*), barracuda (*Sphyraenidae*), spadefish (*Ephippidae*), sicklefish (*Drepanidae*), requiem shark (*Carcharhinidae*), drum/croaker (*Sciaenidae*), mullet (*Mugilidae*), cobia (*Rachycentridae*), parrotfish (*Scaridae*), hammerhead shark (Sphyrnidae), needlefish (*Belonidae*), wrasse (*Labridae*), and bream (*Nemipteridae*). A single inferior pharyngeal bone from a freshwater cyprinid species, *Rutilis frisii*, was also noted in these levels. This may represent a traded item from the interior Caspian sea area (Badstöber 2000: 116). Most of the identified groupers belonged to *Epinephelus* spp. The commonest genera of carangids were the golden trevally (*Gnathanodon speciosus*), followed by queenfish (*Scomberoides* spp.) and *Carangoides* spp. Grunts were represented by the genus *Pomadasys*. Seabream were completely dominated by king soldierbream (*Argyrops spinifer*), followed by smaller quantities of the genus *Acanthopagrus*. Only very small quantities of the goldstriped/haffara seabream (*Rhabdosargus* sp.) were noted. Scombrids largely consisted of longtail tuna (*Thunnus* spp.), with smaller quantities of kawakawa/little eastern tuna (*Euthynnus affinis*) and narrow-barred Spanish mackerel (*Scomberomorus commerson*). Unfortunately, the retrieval method used to collect the faunal remains at Siraf is not mentioned in the thesis by Badstöber (2000). Although seabream dominated, many of these belonged to *Argyrops* which represents one of the largest genera in this family within the region, compared to the usually smaller genus *Rhabdosargus*, which only occurred in low numbers at the site. Recovery biases may thus have partly exaggerated the importance of some of the larger species at Siraf like jacks/trevallies and tuna/mackerel, particularly if the material was largely collected by hand retrieval alone.

Early Islamic levels from Siraf (phase 1B, 725/755 – mid-9th c. AD) produced a very similar picture to that in the preceding period. The assemblages was dominated by seabream, followed by grunts, tuna/mackerel, jacks/trevallies, groupers, sea catfish, emperors, snappers, and barracuda. Smaller quantities of spadefish, requiem shark, cobia, sicklefish, drum/croaker, parrotfish, mullet, eagleray, sawfish, wolf herring, and triggerfish were also noted. The same genera dominated as in the preceding Sasanian/Early Islamic period.

At Jazirat al-Hulaylah in the northern Emirates, close to the Straits of Hormuz, the assemblage was dominated by tuna followed by seabream (Beech 1998). Other fishes represented included jacks/trevallies, followed by emperors, barracuda, eagleray, unknown shark/ray/skate, grouper, requiem shark, flatheads, parrotfish, needlefish, snappers and grunts. Carangids were predominantly represented by the genus *Carangoides*, with golden trevally (*Gnathanodon speciosus*) also being noted. Seabream were dominated by the goldstriped/haffara seabream (*Rhabdosargus* sp.), the genus *Acanthopagrus* also being represented. Scombrids were mostly represented by longtail tuna (*Thunnus* spp.). At Jazirat al-Hulayla systematic dry sieving of all excavated contexts was carried out using a 4mm mesh rocking sieve. This means that we can be more certain about the relative occurrence of particular taxa than at Siraf. It is worth noting that *Rhabdosargus* was the commonest seabream reported here. Smaller fish with bones <4mm may of course be underestimated due to recovery or preservational biases.

In summary, during the Sasanian, Late pre-Islamic and Early Islamic periods, fishing continued in both coastal inshore waters as well as in deeper offshore waters. The location of Siraf on the Iranian side of the Gulf and Jazirat al-Hulaylah, near the Straits of Hormuz, the entrance way to the Gulf, allowed communities at both sites to exploit pelagic fish like tuna and large jacks/trevallies. There appeared to be some regional variation in the occurrence of other species. King soldierbream (*Argyrops spinifer*) comprised a far higher proportion of the seabream at Siraf than at Jazirat al-Hulalah on the southern Gulf coast, where goldstriped/haffara seabream (*Rhabdosargus* sp.) were the dominant sparid genus. Grunts (*Haemulidae*), particularly the genus *Pomadasys*, were also more frequent at Siraf on the Iranian coast. Sea catfish (*Ariidae*) occurred in moderate quantities at Siraf but were not recorded at Jazirat al-Hulaylah. Some of these differences in the occurrence of particular species may simply be due to recovery or preservation biases, nevertheless pelagic taxa like tuna and large jacks/trevallies do generally appear to be more common at both these sites than at earlier sites located on the other side of the Gulf.

4.1.5. Mid-Late Islamic periods

Excavations of the upper levels of the Great Mosque at Siraf also uncovered levels dating from the late 11th-late 13th century (phase 3) and late 13th-early 16th century AD (phase 4). During phase 3, the assemblages was dominated by tuna/mackerel (*Scombridae*), followed by seabream (*Sparidae*), grunts (*Haemulidae*), groupers (*Serranidae*) and jack/trevallies (*Carangidae*) (Badstöber 2000). Smaller quantities of requiem shark (*Carcharhinidae*), followed by barracuda (*Sphyraenidae*), emperor (*Lethrinidae*), snapper (*Lutjanidae*), sawfish (*Pristidae*), sea catfish (*Ariidae*), goatfish (*Mullidae*), parrotfish (*Scaridae*), remoras (Echenidae), drums/croakers (*Sciaenidae*), sicklefish (*Drepanidae*), spadefish (*Ephippidae*) and triggerfish (*Balistidae*) were also recorded. Carangid genera represented included *Carangoides*, *Decapterus* and Seriola, but all only in small quantities. Seabream mostly were either king soldierbream (*Argyrops spinifer*) or *Acanthopagrus* spp. Amongst the scombrids, both the kawakawa/little eastern tuna (*Euthynnus affinis*) and longtail tuna (*Thunnus* sp.) were important, with smaller quantities of narrow-barred Spanish mackerel (*Scomberomorus commerson*) also being caught.

During phase 4 at Siraf (late 13th-early 16th century AD), the small assemblage of fish bones again suggested that seabream (*Sparidae*), grunts (*Haemulidae*) and tuna/mackerel (*Scombridae*) were of some importance. Other fishes represented in smaller quantities included jacks/trevallies (*Carangidae*), groupers (*Serranidae*), sea catfish (*Ariidae*), emperors (*Lethrinidae*), snappers (*Lutjanidae*) and spadefish (*Ephippidae*). *Argyrops* was again the most common seabream, and both *Thunnus* and *Euthynnus* were the major scombrids exploited.

As stated earlier in the preceding section, a major consideration to be taken into account in evaluating the fauna from Siraf is the recovery method used to retrieve the bones at the site. It is not entirely clear to what extent this has biased the results presented by Badstöber (2000). Certainly the numbers of small fish may have been underestimated. The complete absence of sardines, anchovies, as well as the occurrence of only single specimens of fish like wolf herring (*Chirocentridae*) and bream (*Nemipteridae*) indicate that few smaller fish were recovered by whatever collection method was utilised.

Two reports have been published as a result of the international excavation project established at Julfar in Ras al-Khaimah emirate in the UAE (Figure 9, no.18; Figure 109). Excavations at this important mid-14th –16th century AD Portugese trading port and settlement were carried out by archaeological teams from Britain, France, Germany and Japan between 1988-1993. A preliminary examination of fish remains from the earliest deposits (level 6) from the Japanese excavation (Beech 1998) revealed that the assemblage was dominated by tuna/mackerel (*Scombridae*), followed by jacks/trevallies (*Carangidae*), and herrings/sardines/shads (*Clupeidae*). Other fish occurring in smaller quantities included grunts (*Haemulidae*), seabream (*Sparidae*), mojarra (*Gerreidae*), emperors (*Lethrinidae*), barracuda (*Sphyraenidae*), groupers (*Serranidae*), requiem sharks (*Carcharhinidae*), unknown shark/ray/skate (*Chondrichthyes*), and bream (*Nemipteridae*). Both *Carangoides* and *Caranx* were represented amongst the carangid genera. The grunts all belonged to the genus *Pomadasys*. Seabream were represented by both *Argyrops* and *Rhabdosargus*. Scombrids were represented by both longtail tuna (*Thunnus* sp.) as well as by Spanish mackerel (*Scomberomorus* spp.). Two of the excavated contexts, ovens 131 and 134, contained large concentrations of fish scales which appeared to belong to *Pomadasys* (Beech 1998). All excavated contexts at this site were dry sieved using a 4mm mesh screen. A number of contexts were also sampled to be dry sieved through a finer 1mm mesh screen. The presence of fish like herrings/sardines/shads, mojarra and bream, as well as the recovery of fish scales, indicates that smaller fish were of some importance at this site.

Analysis of the fish remains from the contemporary French team excavation area reveals a broadly similar picture (Desse and Desse-Berset 2000). The most common fish represented were tuna/mackerel, closely followed by jacks/trevallies, emperors, seabream, mullet (*Mugilidae*), mojarra (*Gerreidae*), herrings/sardines/shads, bream, snappers (*Lutjanidae*), rabbitfish (*Siganidae*), groupers, terapons (*Teraponidae*), grunts, marlin/sailfish (*Istiophoridae*), barracuda (*Sphyraenidae*), hammerhead shark (*Sphyrnidae*), sea catfish (*Ariidae*), needlefish (*Belonidae*), and parrotfish (*Scaridae*). The commonest genus represented amongst the jacks/trevallies was the torpedo scad (*Megalaspis cordyla*), followed by queenfish (*Scomberoides* spp.), *Atule*, *Carangoides* and golden trevally (*Gnathanodon speciosus*). Goldstriped/haffara seabream (*Rhabdosargus* sp.) was the commonest genus of seabream represented, followed by *Acanthopagrus* spp. Most of the scombrids belonged to kawakawa/little eastern tuna (*Euthynnus affinis*) and yellowfin/longtail tuna (*Thunnus* spp.). Moderate quantities of narrow-barred Spanish mackerel (*Scomberomorus commerson*) were also present. A notable discovery in the French excavation area at Julfar was the presence of marlin/sailfish, which was represented by an articulated tail section comprising a caudal peduncle and four caudal vertebrae (Desse and Desse-Berset 2000: 86, fig.8-d). No earlier finds of this family have been so far reported from sites in the Gulf. Unfortunately the retrieval methods used to recover the faunal assemblage during the French team's excavations at Julfar are not detailed in the recently published report (*op. cit.*). Judging by the presence of taxa like sardines/herrings/shads (*Clupeidae*), mojarras (*Gerreidae*) and breams (*Nemipteridae*), some sieving may have been carried out. Unfortunately it is not clear from the report where the material originated from on the excavation and what proportion of it may or may not have been sieved.

In summary, during the mid to Late Islamic periods, fishing appears to have continued to exploit both inshore coastal waters as well as deeper offshore waters for a number of pelagic species. Tuna and mackerel continued to be of some importance. However, the fact that systematic sieving has not been carried out at several sites means that the quantities of smaller fish may have been underestimated.

4.2. Archaeological evidence for fishing technology

As well as the already published fish zooarchaeological data, there is also various surviving archaeological evidence for the adoption of particular fishing technology in SE Arabia which can be considered. Past studies of archaeological fishing equipment have demonstrated that changes in the technology employed in coastal fishing may reflect developmental changes in the organisation of fishing (e.g. Anell 1955; Coutts 1975; Hurum 1976). In SE Arabia a range of artefacts associated with fishing have been discovered on coastal sites, including stone netsinkers and fish hooks made from shell and copper (Figure 19). The location of the major sites with such finds mentioned in the following sections are depicted in Figures 9-10.

4.2.1. Netsinkers

Probably the commonest traces of fishing equipment found on archaeological sites in the region are stone netsinkers. These have been found at coastal sites in the Gulf as well as along the coast of Oman. It is generally assumed that these were used in conjunction with fishing nets of some sort, on the basis of their general size and weight. Stone anchors so far discovered in this region during underwater archaeological surveys tend to be much larger and more substantial (Tom Vosmer, pers. comm.). Larger netsinkers may have been used in conjunction with gill nets or beach seines. Small examples may have used in conjunction with casting nets. It is also possible that some of them may have been used as line sinkers to weigh down a line baited with a number of hooks.

A number of different types of netsinker exist in this area. Whilst some of these do appear to have some chronological significance, in other cases they appear to be more part of certain local traditions (Uerpmann 1992: 94-96). It is interesting to note that netsinkers appear to have received much more attention than the chipped stone industry in reflecting the materialized expression of group identity (Uerpmann 1992: 96). Simpler more functional explanations may account, however, for some of these apparent differences.

The first type of netsinkers are flat oval pebbles, notched roughly in the middle of their long sides (Figure 20). They occur at a number of Omani coastal sites belonging to the Saruq to Bandar-Jissa-Facies, i.e. dating to between about 5500-3500 BC (Uerpmann 1992: 94), but can be also found at some later sites. These simple notched pebbles were the major type of netsinker reported at Ra's al-Hamra RH5 (Durante and Tosi 1977). A variation on these are simple notched netsinkers which are sometimes 'retouched' along their outline, being flaked on one side with careful notches being made at each end (Figures 21-22). Examples of this type were discovered at Khor Milkh 1 in Oman, a site broadly contemporary with RH5. At the later site of Khor Milkh 2, which is only about 300 years later than Khor Milkh 1, however, only the simpler first type were present, along with an example with a large pecked waistline and additional notches in its ends (Figure 23). Some sites like Al Haddah (BJD1) in Oman, also have these notched netsinkers some of which were quite large between 5-7cm (Figure 24). Other examples have also been reported from other coastal sites in the Ja'alan region of Oman, including Khor al-Hajar (KHJ2), Ra's al Khabbah (KHB1), Ruways (RWY1) and Suwayh (SWY2) in Oman (Charpentier et al. 1997: 103).

A second type of netsinker found at some sites are small and relatively thick pebbles which have a pecked shallow groove around the "waistline" of the pebble, facilitating the attachment of lines. These smaller netsinkers are generally not bigger than about 2.5 - 3 cm. Such netsinkers appear to be especially common during the early 5^{th}-4^{th} millennium BC at a number of sites along the Omani coast (Charpentier et al. 1997: 103). Examples of this type have been found at Saruq (Uerpmann 1992: 95) and at BJD1 at Al Haddah (Figures 25-26).

Similar netsinkers have also been discovered at Nad al-Walid, a shell midden located near Jazirat al-Hamra in Ras al-Khaimah, UAE, which is broadly contemporary with Saruq. It is interesting to note, however, that this particular type of net sinker has not been found at the broadly contemporary sites at Ras al-Hamra in Oman. A further variation on these small netsinkers with a pecked waistline are examples which have a sawn-in waistline. These are known from Ras al-Hamra 6, which is partly contemporary with Saruq, and one example of this type (Figure 25-h) is also known from Saruq (Uerpmann 1992: 95). Examples with pecked waistlines are known, however, in later contexts but only on quite large netsinkers. At Umm an-Nar in the UAE, similar larger netsinkers with pecked waistlines have been discovered in the 3rd millennium BC settlement (Figures 27-28).

A third type of netsinker and the commonest type found at Umm an-Nar, however, was made from the local limestone (Frifelt 1995: 113). These were usually circular, flattish and perforated and were found in all levels of the excavation. A total of 201 netsinkers were recovered, of which 182 had their weight recorded. A good proportion of these came from House 227/228 and Area 499. All were between 1.5 - 5cm thick and had a diameter often less than 10cm. Examples of some of these can be seen in Figures 29-32. The Umm an Nar netsinkers varied in weight from quite small examples less than a 100g in weight to more substantial examples of 0.5kg plus (Figure 33). The majority were between 100-200g in weight.

Other artefacts which may have been utilised in fishing are so-called "perforated disks". These have been found at a wide range of sites throughout the area from sites dating between the 5th-3rd millennium BC. Examples are known from the early 5th millennium BC site on Dalma island (Figure 34), as well as from the 3rd millennium BC settlement at Umm an-Nar (Figure 35). Some of these are made from stone whilst others appear to be made from ceramics (?re-used broken pottery vessels). The precise function of these is not known but various hypotheses have been suggested for them including their use as spindle whorls or items of jewellery. A further possibility is that they may have been used in fishing equipment. Smaller net sinkers and perforated disks could have easily been used with casting nets. These are occasionally used in the traditional local fisheries of the region (Chapter 3.9). Casting nets were certainly known from early periods and are even mentioned in the New Testament (Matthew 4:18; Mark 1:16; John 26:6-11). The casting net is cast in a ring about a school of fish and encloses the prey from the sides and from above but not from below. Even though some of the perforated disks seem quite light and unsuitable to weigh down nets, once these are immersed in water they may have acted as effective tracers holding the position of the net in the water. The author has witnessed very similar small disks being sold with such nets in the UAE.

Little published data concerning netsinkers are available for later period sites in the Gulf and SE Arabia. It is clear though that predominantly locally available materials were used to manufacture netsinkers in the various regions. In the southern Gulf, as at Umm an-Nar, the inhabitants continued to use the locally available limestone as it was almost the only source available to them. In the northern Emirates harder granite-like stones were more readily available and could be used to manufacture netsinkers, e.g. the quite large 9.5cm early Islamic example discovered at Jazirat al-Hulaylah (Figure 36).

4.2.2. Shell fish hooks

There is a considerable body of literature concerning traditional fishing equipment, and in particular the use of fish hooks within the tropics, particularly in Polynesia and the Pacific (e.g. Anell 1955; Best 1929). One of the problems in interpreting the precise use of fish hooks is that very few detailed studies have been made connecting preserved hook-types with particular fishing methods. This is often because metal hooks have been used for over a century in many parts of the world, and traditional knowledge has been lost and not recorded.

The earliest fish hooks in SE Arabia are made of marine shell, usually from pearl oyster or large bivalves. Examples have been recovered from a number of coastal sites in Oman (Figures 37-41) dating between the early 5th – late 4th millennium BC, including Khor Milkh 1 and 2, Ra's al-Hamra RH5, Ra's al-Hadd, Ra's al-Jins RJ2, Ra's al-Khabbah KHB1, and Suwayh SWY2 (Biagi and Nisbet 1989; Charpentier and Méry 1997; Phillips and Wilkinson 1979; Uerpmann 1992).

The deliberate selection of such a raw material may have been advantageous for a number of reasons. Shells were in plentiful supply along the entire coastal regions of SE Arabia. It was fairly easy to work the shell into the desired equipment, and the material itself was hard and durable. A further advantage of using shells with a shiny/glistening surface was that this worked as an attraction device to entice fish to bite. It is even reported in some parts of the tropics that such hooks do not even require any bait, as the glitter of the pearl shell is far more attractive to the fish (Anell 1955: 146). In some parts of Polynesia (e.g. the Luisiades) it is even reported that the natives had such effective hooks of their own that they preferred them to European steel hooks.

Grooves incised across the top of the shanks of these hooks enabled fishing lines to be bound to them, and some hooks had a pair of holes drilled in the top of the shank where lines could be tied. The shell hooks found along coastal sites in SE Arabia all appear to be unbarbed. This appears to follows the general rule that the earliest fish hooks were made without any barb or refinement, only after thousands of years did they regularly become equipped with barbs as well as grooves, bulges and holes (Hurum 1976: 25). Hooks without barbs generally help the fishermen save time and avoid damage to the fish. The fish can be literally just shaken off the hook. Even though some fish may be lost whilst hauling them in this does not matter if it is at a time of year when there is a super abundance. In the Pacific fishing for bonito has for centuries used a method whereby barbless hooks are utilised from a stationary vessel carrying live bait. In the case of very large tuna, individual lines may be manned by two men using two rods attached to the same line (Hurum 1976: 86). Some of the fish hooks found along the Omani coast do have incurved points. This may have been a deliberate choice as unlike barbed hooks they would not get so easily stuck on the bottom.

Shell fish hooks are strong and can be used to capture quite large fish. In western Melanesia hooks of mussel shell, mainly *Trochus*, are commonly used to catch specimens as big as sharks. The lower part of the fishing line is protected from the shark's teeth by a hollow stick through which it is drawn (Anell 1955: 87). Some of the shell fish hooks had quite long shanks and this may have been deliberately manufactured like this to be more effective if the particular fish being caught had sharp teeth to prevent them cutting through the leader (Hurum 1976: 82-3).

It is possible that other raw material may have been also used in the past to manufacture fish hooks in SE Arabia. Three examples of fish hooks made from dugong bone are known from the Huon Gulf and the Sepik River in Polynesia (Anell 1955: 88). G. Landtman observed in 1927 that hooks made from marine turtle shell were amongst the commonest types of hooks in use in the Torres Straits area, and by the Kiwait Papuans of British New Guinea (cited in Anell 1955: 142). It is reported that hooks were made out of a piece of turtle-shell which was cut narrow and ground on a stone. Both ends were sharpened on the stone and bent over a fire, after which the piece of shell was cut in two, so as to form two fishhooks.

Something which is rather curious is why no shell fish hooks have been so far discovered/published from sites within the Arabian Gulf. This may simply be a result of the greater focus and intensity of research on early coastal sites on the Omani coast. No shell fish hooks were discovered by Abdullah Masry in the late 1960s at any of the Ubaid sites he investigated on the Saudi Arabian Gulf coast. None have been found at the recent excavations of the Ubaid settlement on Dalma island, UAE (Flavin and Shepherd 1994; Beech and Elders 1998). Only relatively small areas have been excavated on these sites so they may have simply been missed. A possible shank of a shell fish hook has been collected from the surface of site MR1 on Merawah island, during a field survey carried out by the Abu Dhabi Islands Archaeological Survey project. This unfortunately is not from a provenanced context although the site itself has been radiocarbon dated to the late 6th millennium BC. It is also possible that the general absence of shell fish hooks within the Gulf reflects the different marine conditions existing between the two areas. The deeper waters immediately lying close to the Omani coast would have made hook and line fishing an attractive proposition, in contrast to the exceedingly shallow waters of much of the Gulf where basket traps and intertidal barrier traps may have been often preferred. Another possibility is that hooks were so highly prized by their owners that they were carefully curated and had comparatively little chance to enter the archaeological record. Hooks may have been highly valued by their owners. In Tahiti, for example, it is reported that fisherman were unwilling to sell their inherited hooks to strangers. An old and highly successful hook used to catch bonito was considered to be ....

".... property almost beyond price, cherished not only for its utilitarian value, but because in the course of forty of fifty years it has acquired in the catching of countless fish a tremendous charge of mana ('magical property')" (Anell 1955: 176).

Something which should be also taken into account is the fact that some of the coastal sites situated on the Omani coast were clearly workshops for the production of fish hooks and shell beads like *Engina mendicaria*. This means that shell fish hooks may have had a greater chance of inclusion in the archaeological deposits if they were broke, discarded or accidentally dropped. One of these 5th-4th millennium BC workshops was identified at Suwayh where a number of curious limestone tools were discovered (Figure 42). It has been suggested on the basis of strong ethnographic parallels with known examples from Hawaii and other sites in the Pacific, that these tools were used in the production of shell fish hooks (Charpentier and Méry 1997: 150-3, figs. 4-5). On the island of Tahiti, Sir Joseph Banks observed that ...

"the shell is first cut by the edge of another shell into square pieces. These are shaped with files of coral, with which they work in a manner surprising to any one who does not know how sharp corals are. A hole is then bored in the middle by a drill [...] the file then comes into the hole and completes the hook" (Best 1929: 32-3).

Other fishing equipment which would have undoubtedly been used in the region were gorges and lures. A number of bone gorges were discovered at Ra's al-Hamra at site RH5 (Biagi and Nisbet 1989; Figure 41). Such artefacts may easily have been overlooked on other excavations. In the Marshall Islands in the Pacific, lures are mostly made from pearl shell, and sometimes from *Spondylus* (Anell 1955: 152). Gorges consisted of a straight stick of shell, bone or wood where the line was attached in the middle. Once baited, the gorges were laid out parallel with the line. Any fish swallowing the bait and attempting to swim away was then trapped as the line is pulled taut and the gorge sticks in the throat or belly of the fish. In the Pacific it is also reported that gorges can be made from tortoise shell and even out of mangrove wood, and in New Zealand slightly curved gorges are made out of mussel shell (Annell 1955: 73-5).

4.2.3. Metal fish hooks

Once copper and bronze came into use it became possible to manufacture fish hooks from metal. Copper started to be used from approximately 4000 BC followed by the gradual development of bronze. Once fish hooks began to be manufactured they were even used for barter and in later periods even as coinage (Hurum 1976).

Some of the oldest fish hooks known from the region are examples from Ur in Mesopotamia dating to about 2600 BC (Figure 43). These are unbarbed hooks made from copper. Curiously broadly contemporary fish hooks from sites like Lothal within the Indus valley civilisation have barbs (Figures 43-44), suggesting that distinctive regional trends in technology (as in the case of netsinkers) may have been adopted. On the Omani coast unbarbed hooks are also found similar to the Mesopotamian examples. An almost complete copper fish hook and fish-hook fragment (Figure 45) were discovered at the 3rd millennium BC site of SWY-3 at Khor Bani Bu Ali, about 70km south of Ra's al-Hadd (Méry and Marquis 1998). These fish-hooks have a long tradition in the region from the beginning of the third millennium BC at Ra's al-Hadd HD-6 and continue after 2500 BC at Ra's al-Jins RJ-2 (Cleuziou and Tosi 1986: fig. 19 nos. 2-4; 1988: fig. 18 no. 6, fig. 19, fig.20 no. 2) and Ra's al-Hadd HD-1 (Cleuziou, Tosi and Reade 1990: fig. 35). The same type of unbarbed copper fish-hooks were also reported at the settlement of Umm an-Nar (Frifelt 1995), both within the 3rd millennium BC graves as well as within settlement contexts (Figures 46-52). Two examples were found in graves I and V at Umm an-Nar but the majority of the fish hooks, a total of 14 fragments, came from the settlement (Frifelt 1991, 1995).

Copper/bronze fish hooks may have been used for a considerable period of time. It is not until the early Islamic period when other metals such as iron are used in the manufacture of hooks. Examples of such fish hooks have been found at both Jazirat al-Hulaylah and Julfar in Ras al-Khaimah in the northern Emirates (Figures 53-54).

4.2.4. Other equipment

Other evidence of fishing equipment utilised in the region include the occasional discovery of metal harpoons or tridents. Bronze fish-tridents are known from Mesopotamia (Saggs 1965: 131, fig.75). A possible fishing spear (Figure 55) was also reported from the 3rd millennium BC settlement of Umm an-Nar, reportedly discovered on the spoil heaps of one of the trenches! (Frifelt 1995: 71).

Harpoons or tridents may be used to catch rays and sharks, and in the Torres Straits in Australia such equipment is used to catch dugongs (Anell 1955: 66). Dugong bones were also recorded at the Umm an-Nar settlement (Chapter 2.2.4). Harpoons are also used by the Kiwai Papuans to hunt marine turtle and by Mimika natives in SE Asia to catch sawfish (Anell 1955: 67). Again both these taxa were represented in the bone assemblage at Umm an-Nar.

4.2.5. Fish traps

Fish traps have already been discussed in the preceding chapter on the traditional fisheries of the region. Traps certainly appear to have been particularly favoured along the shallower waters of the western and southern Gulf. As stated earlier, there is comparatively little archaeological evidence for the use of traps largely because the majority may have been made of organic materials which simply do not survive. The recent unearthing of a whole series of stone wall fish traps on offshore islands in the western region of Abu Dhabi is a remarkable discovery. Unfortunately it is very difficult to precisely date these structures. As they are situated in the present intertidal zone it seems likely that they belong to the Islamic period and since 1000 AD when sea levels attained similar levels to the present day (cf. Table 2). Such traps may of course have been utilised further back in antiquity. The coastal geology of the western Abu Dhabi region, large flat sandy beaches with high salinity and evaporation which often means that the shallow water bottoms develop into a kind of hardened crust of sand, mollusc and coral fragments, making the construction of such traps quite simple. This local beachrock ("farush") could be collected and used to build the walls of these traps.

In the following section, we will go on to consider what documentary sources tell us about the historical development of fishing in SE Arabia.

4.3. Documentary sources

Our earliest documentary records referring to fish come from the remains of cuneiform tablets from Mesopotamia, modern day Iraq. Many of the 3rd millenium BC cuneiform tablets from Mesopotamia are concerned with the movements of commodities of various kinds. One example is a text from the palace archives at Larsa, where reference is made in one particular text (Text 10:9) to the sale of a concession to palace goods which includes "...sea-fish, dates, garlic and wool..." (Jean 1931, no.106; Postgate 1992: 198). According to the epic linguistic work by Armas Salonen entitled "*Die Fischerei im alten Mesopotamien*", Sumerian and Akkadian texts provide us with linguistic evidence for the names of at least 40 different types of sea-fish (Salonen 1970: 242). Although the texts mostly refer to freshwater fish which presumably originate from the Tigris and Euphrates rivers and their tributaries, the names of a number of specific marine fish are also mentioned. Salonen makes a brave attempt to decipher which traditional names in the ancient Sumerian and Akkadian scripts match with present fish in the region based on linguistic and pictorial evidence. This is extremely difficult particularly as the names of some fish clearly change completely between the different languages. Salonen nevertheless suggests that 21 families including at least 28 species can be determined. The names specifically listed in the texts include the following fishes: requiem sharks (*Carcarhinidae*), hilsa shads (*Clupeidae*: *Hilsa* spp.), needlefish (*Belonidae*), scorpionfish (*Scorpaenidae*), flatheads (*Platycephalidae*), helmet gurnards (*Dactylopteridae*), groupers (*Epinephelus* spp.), sillagos (*Sillaginidae*), jacks/trevallies (*Carangidae*), grunts (*Haemulidae*), drums/croakers (*Sciaenidae*), threadfins (*Polynemidae*), spiny turbots (*Psettodidae*), soles (*Soleidae*), tonguesoles (*Cynoglossidae*), pomfrets (*Stromateidae*), cutlassfish (*Trichiuridae*), Spanish mackerel (*Scomberomorus* spp.), sicklefish (*Drepanidae*), scats (*Scatophagidae*) and tripodfish (*Triacanthidae*) – (Salonen 1970: 239-242).

We know that there were even professional fishermen in Mesopotamia already by this time. These presumably were largely concerned with fishing the local freshwater rivers. The art of breeding fish in ponds seems to have been already known judging from the well known Assyrian reliefs depicting these scenes. Fish ponds were also built as adjuncts to Sumerian temples (Radcliffe 1926: 378). Fish offered for sale and mentioned in these texts may have been fresh, dried, salted or smoked. Although it has generally been assumed that fish was a common dietary item and a valuable source of protein. They may however have primarily been luxury items, poorer people largely having a diet consisting of vegetable products (Saggs 1965: 175).

A number of Mesopotamian myths refer to the Gulf area and to the supposed origins of civilisation. One of the Sumerian myths in common circulation was the description of how the water-god Enki (also the god of wisdom) had created the world order. This myth primarily describes the state of human achievement at the time of the coming of the Sumerians into Mesopotamia. Two thousand years later, Berossus, a Babylonian priest writing an account in Greek of the supposed origins of civilisation in the 3rd century BC, wrote that:

"In the first year [of the world] there appeared, from the Persian Gulf, a being named Oannes. His whole body was that of a fish. Under the fish's head he had another head, and joined to the fish's tail were feet like those of a man... This being used to pass the day among men and gave them knowledge of written documents and all kinds of knowledge and crafts. He taught them to construct cities, to found temples, to compile laws, and to survey the land; and made known to them the use of seeds and the gathering of fruit. In short, he instructed them in everything necessary for daily life."

Further pictorial evidence of fish in everyday activities like food preparation, sacrifices at temples through to depictions of Oannes, the Babylonian and Assyrian half-fish/half-man god, all demonstrate the importance and value assigned to fish in these early societies.

The earliest written references to fishing specifically along the coastline of the Arabian Peninsula and its neighbouring areas come from Greek sources. As has been earlier indicated (Chapter 2.2.1), foremost among these are the account of the voyage of Nearchus in the 4th century BC as recounted in Arrian's *Indica* (Brunt 1983) and the anonymous *Periplus of the Erythraean Sea* of around AD 100 (Huntingford 1980). Both these sources refer to certain communities living on the Arabian and Makran coastlines as the *Ichthyophagi*, i.e. the fish-eaters. This suggests that fishing was certainly a major component of coastal life in the region.

In Arrian's account, Nearchus described on the Makran coast the catching of anchovies and sardines by castnet, fishing craft propelled by paddles rather than oars, and a "flour" or "meal" made from grinding dried fish (Brunt 1983: 385-401). A similar description is also made in the *Periplus* which adds that dugout canoes and fish traps were also used (Schoff 1912: 28; Huntingford 1980: 29-30). It is noted that the coastal communities had such plentiful supplies of fish that they even fed their domestic livestock with fish (Brunt 1983: 393). Arrian remarks that Nearchus observed fishermen on the Makran coast fishing close to the shore with nets, which sound from their description like beach seines. He also commented on the use of castnets by these coastal communities. The beach seines were described as being about "two stades in length" and made from the plaited, twisted bark of the date-palm (Brunt 1983: 393). Nearchus also reported the presence of pearl fishing in the Arabian Gulf.

Other important historical sources which mention fish or fishing in the Arabia region belong to a number of medieval and later descriptions. These have been recently reviewed by Donaldson (2000). Ibn Hawqal, the Arab geographer, traveller and merchant from Upper Iraq, published "*Kitab al-Masalik wa-al-mamalik*" (also known as "*Kitab Surat al-ard*"). As Donaldson comments, this source appears to be highly dependent in places on the work of the 4th/10th century geographer al-Istahri, but it does mention the importance of pearl fishing at certain locations including within the Arabian Gulf. Ibn Hawqal also provides a fascinating description of the coastal communities living on the Makran coast...

"There are no date-palms or sown crops here, and their possessions are only camels and goats and camels and beasts of burden, which are fed with the small fish known as *waraq*. Neither the people nor their animals are acquainted with bread and they do not eat it, their food being fish, dairy products and dates." (Ibn Hawqal n.d., cited in Donaldson 2000: 12).

As Donaldson points out, the small fish referred to here may be sardines, although the present day name for anchovies in the Dhofar region of Oman is "garaq" so it may not refer to sardines, but rather to anchovies.

In the early 7th/13th century Ibn al-Mugawir wrote a series of itineraries in the Hijaz and Yemen, interspersed with observations and stories about the places mentioned (Løfgren 1951-4). He describes the Omani port of Qalhat in some detail and says that its fishermen unsurprisingly lived on the shore. Ibn al-Mugawir also recalls that fishermen living on the island of Qays, on the Iranian side of the Arabian Gulf, ate fish and that they made a kind of mash ("harisah") with it from cracked wheat and meat, and that this was eaten with dried dates. He says that the people had no foods other than this (Donaldson 2000: 13). Discussing the coastal populations inhabiting the Dhofar region near Salalah, he says that the people there only thickened their harisah with fish-meat and nothing else. When talking about the people of al-Mansurah he says that...

"Their food is fish, *dhurah* [sorghum/millet], and *kanib*. The fodder of their animals is dried fish which is [called] *'ayd*, and they fertilise their land with nothing but fish." (Ibn al-Mugawir, cited in Donaldson 2000: 14).

In the 1290s Marco Polo, the famous Venetian explorer, visited both the southeastern coasts of the Arabian peninsula and the Hormuz area at the entrance to the Arabian Gulf. After describing the (to him) strange sheep of the port of al-Shihr on the Makran coast, he says:

"And here is something else that that may strike you as marvellous: their domestic animals - sheep, oxen, camels, and little ponies - are fed on fish. They are reduced to this diet because in all this country and in all the surrounding regions there is no grass; but it is the driest place in the world. The fish on which these animals feed are very small and are caught in March, April and May in quantities that are truly amazing. They are then dried and stored in the houses and given to the animals as food throughout the year. I can tell you further that the animals also eat them alive, as soon as they are drawn out of the water. There are also big fish here - and good ones too - in great profusion and very cheap." (Latham 1958: 309-10).

The small fish he refers to are presumably sardines or anchovies, like in the earlier accounts, whereas the "big fish" may refer to tuna species. Marco Polo's account is the first historical record which specifically mentions the seasonal variation in fish catches. It also importantly mentions the fact that some fish were dried and stored for later use at other times during the year. Polo describes how smaller fish were sun-dried whilst tuna species were cured by salting (Latham 1958: 66, 296, 309). He also says that at al-Sihr, a "biscuit" of chopped dried fish (?shark) was manufactured for human consumption (Latham 1958: 310). Polo also observed that at Hormuz one by-product of fish was a type of oil which was used to preserve ships' timbers (Latham 1958: 66). It has been suggested that this may be blubber from beached whales, sardine oil collected in pits on the beach or shark liver oil, extracted by boiling (Donaldson 2000: 16).

The famous Ibn Battutah also visited the region. Having set off from his home in Tangiers in 1325, he visited Arabia at least twice including the Hijaz, the Yemen, Aden, Oman and the Arabian Gulf. His travelogue was subsequently dictated to a Maghreb scholar, Ibn

Guzayy, about four years after his return (Gibb 1958, 1961, 1971; Beckingham 1994). Ibn Battutah describes Masirah Island, off the SE coast of Oman as being a place where the people had no subsistence other than from fish. The inhabitants of Hasik, a port located to the east of Salalah, reportedly had houses built using "fish" bones (?whale bones) roofed with camel hide. They reported preparing some sort of dried shark product:

"Their fish is known as *lukh(a)m* and is similar to the *kalb al-bahr* (shark). It is cut open (*yushrah*), and cut lengthwise into strips and dried [in the sun] (*yuqaddad*)." (Gibb 1962: 258).

As Donaldson points out, the term *luham/luhm* is still the name used for shark in southern Arabia today, although in northern Oman and the southern Gulf including the UAE it tends to be referred to by the generic name "*jarjur*" (Donaldson 2000: 19). In the UAE, however, the term "*lukhma*" seems to be used to describe rays and skates. Ibn Battutah also mentions a number of other fishes. These include the fact that a member of the tuna/mackerel family (Scombridae) was common in catches at Muscat in Oman., and that sardines were commonly caught at Dhofar in southern Oman, where their beasts of burden as well as goats were fed with these fish (Ibn Battutah 1968).

In the mid-18th century a number of European explorers and scientists begin to visit the area. These include in the 1760s the Danish traveller and scientist Carsten Niebuhr, who travelled through the Yemen, Oman and the Makran coast of Iran (Heron n.d.). He observed a similar picture to that portrayed by earlier authors, and commented on the fact of how little appeared to have changed with these coastal communities since the "ichthyophagi" of classical times. During the 19th century a number of British Indian army and navy officers provided additional accounts which occasionally mention fish, fishing and fish trading although these are rarely systematic accounts. Lt. G.B. Kempthorne followed Nearchus' route along the Iranian coast and noted that its inhabitants and those of the Arabian coast opposite subsisted largely on fish and that they also fed fish to their livestock (Kempthorne 1835). In the 1830s, Lt. F. Whitelock repeated similar observations, and added that off Khasab on the Musandam Peninsula the main types of fish caught were mullet (*Mugilidae*), Spanish mackerel or kingfish (*Scombridae*: *Scomberomorus* spp.) and various "rock fish" (Whitelock 1838a,b,c). Around the same time, Lt. J.R. Wellsted commented that one of the principal exports from the port of Muscat was shark fins destined for China as well as salt fish (Wellsted 1837, 1838). Lt.Col. L. Pelly, writing around 1860, stressed the importance of the export of salt fish and also of pearls to the economy of what is now the coast of the

United Arab Emirates (Pelly 1863). According to him, the main export markets for the fish were Zanzibar (which, until 1865, was still part of the Omani "Empire"), the East African coast and the Malabar coast of India. Pengelley also published an account in 1860 in which the people of the Batinah coast of Northern Oman were described as subsisting solely on fish and dates (Pengelly 1860). He also provided the earliest written description by a European of a particular kind of fishing craft built of date-palm fronds called the *shashah* which was used both on the Batinah coast as well as within the Arabian Gulf. Records concerning fisheries are much more detailed from the 1880s onwards. The first attempts to systematically quantify the size of fish catches, numbers of fishing boats and fishermen, were by the British Persian Gulf Political Residency and the Muscat Political Agency (MacIvor 1880-81; Lorimer 1908-15; Miles 1919). It was not until the latter half of the 20th century that any surveys of Arabian fisheries were carried out by fisheries experts (Chapter 3.1).

In summary, based on documentary sources the fisheries of the region appears to have changed little over the course of a considerable number of centuries, if not millennia. Many later observers simply repeat what early sources report. Specific fish which seem to be regularly mentioned are sharks, sardines and tuna, and curing methods such as sun-drying (for small fish like sardines) and salting (for large fish like tuna) are mentioned in some of these sources. Sardines were important not only for food for the coastal populations of SE Arabia, but were also used as food for their livestock and also as fertiliser. A substantial export trade (with India and East Africa) in cured fish and (with China) in shark fins clearly existed from the 19th century onwards, and it is likely that such a trade went on for centuries before this.

4.4. Summary

The goal of this chapter is to examine the chronological development of fisheries in the Arabian Gulf and Gulf of Oman, based on past studies of zooarchaeological, archaeological and historical data.

Does change through time influence the composition of fish faunas in this region?

Fishing at the earliest 5th-4th millennium BC sites located within the Arabian Gulf was largely characterised by the capture of small fishes in sheltered inshore coastal waters. Little fishing appears to have been conducted on reefs and in deeper open waters for pelagic species. This is contradicted by the apparent evidence from the Gulf of Oman (Site RH5), where pelagic fish tuna/mackerel (*Scombridae*) appear to have already been exploited by the 4th millennium (Biagi et al. 1984), indicating that some fishing was carried out in the open seas off the Omani coast. During the 3rd-2nd millennium BC, fishing strategies concentrated not only on shallow inshore coastal waters but also on reef areas as well as deeper offshore waters. Larger fish such as jacks/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) were noted in greater quantities than at the earlier sites. During the Iron age, fishing for larger fish like carangids and scombrids in deeper offshore waters continued but clearly inshore coastal and lagoon areas were also regularly exploited. In the northern Gulf during the Hellenistic period, fishing communities living on Failaka island clearly focused on reef areas, as well as on shallow inshore areas and adjacent areas with mud bottoms and estuaries. In the Ed-Dur period fishing was carried out in both the local shallow lagoon as well as in the open sea for pelagic and larger demersal species. By the 3rd-4th century AD, at the site of Mleiha, fish were already being imported to sites within the interior of SE Arabia. During the Sasanian, Late pre-Islamic, Early and Mid-Late Islamic periods, fishing continued in both coastal inshore waters as well as in deeper offshore waters. There appeared to be some regional variation in the occurrence of certain species within different areas of the Gulf. However, in many cases it was not at all clear whether these differences could be attributed to a combination of variable recovery techniques or the differential survival of different taxa.

What kinds of fishing equipment have been adopted through time?

A review of the archaeological evidence for fishing equipment identified several types of artefacts associated with fishing activities. These were netsinkers, shell fish hooks, metal fish hooks, other equipment like harpoons and tridents, as well as fish traps. Although there were clearly some visible changes in the use of technology through time, there also appeared to be evidence for regional differences. A number of broadly contemporary sites had different types of netsinkers. The earliest type of net sinkers were flat oval pebbles, notched roughly in the middle of their long sides (sometimes being retouched). The second type were small and relatively thick pebbles (ca 2.5-3 cm) with a pecked shallow groove around the "waistline" of the pebble. A third type of netsinker (the commonest type found at Umm an-Nar) was made from local limestone (Frifelt 1995: 113). These were usually circular, flattish and perforated. It has been suggested that the larger netsinkers may have been used with nets, whilst the smaller ones may have been used with hand cast nets (Cleuziou and Tosi 2000: 41). Shell fish hooks were seemingly absent from sites in the Gulf but have been found at a number of sites along the coast of Oman. Copper hooks within the Gulf as well as on the coast of Oman were unbarbed as opposed to a number of barbed examples known from the broadly contemporary Indus Valley civilisation sites.

Does the adoption of new fishing technologies indicate a change in fishing strategies?

It is not clear what is the significance of the various net sinker types. Although functional explanations may explain certain possibilities like deeper water netsinkers and line sinkers vs. hand cast nets (based on their size/weight), it is also possible that they may reflect the materialized expression of group identity (Uerpmann 1992: 96). The apparent absence of shell fish hooks at early period sites in the Gulf may partly be due to the effect that fewer early period sites have been excavated in this region. Tuna were certainly caught, probably using shell fish hooks as early as the 4th millennium BC on the Omani coast at site RH-5 at Qurum (Biagi et al. 1984). Once copper fish hooks became available from the 3rd millennium BC onwards, and copper began to be traded throughout the region, this may have helped to intensify fishing efforts at certain locations. It has been suggested that fishing at Ras al-Jins (RJ-2) on the Omani coast may have been no longer a subsitence activity but a large-scale production for an exchange economy (Cleuziou and Tosi 2000: 42).

Does documentary evidence provide any insight into the history of fish exploitation in this region?

A review of documentary resources connected with fisheries of the Gulf and SE Arabia provides additional information concerning the importance and use of fish through time in this region. Historical sources reveal that little change appears to have taken place over the course of a considerable number of centuries, if not millennia. Sharks, sardines and tuna are often mentioned. Many reports state that sardines (and possibly anchovies) were used not only for human consumption but also as livestock feed and fertiliser. There is documentary evidence for a substantial export trade (with India and East Africa) in cured fish and (with China) in shark fins clearly from the 19th century onwards.

The following chapter will present the results of the analysis of 23 recently excavated fish bone assemblages from the Arabian Gulf and Gulf of Oman, which have all been collected using systematic recovery techniques. The existing model presented in this chapter will subsequently be assessed and the regional trends evaluated in the light of this new zooarchaeological data (Chapter 5), as well as modern fisheries information (Chapter 3).

CHAPTER 5

THE ZOOARCHAEOLOGICAL ASSEMBLAGES: METHODS AND RESULTS

This chapter outlines the results of the zooarchaeological analysis of 23 sites located in the Arabian Gulf and Gulf of Oman. It provides the primary data for the analysis which continues in the following chapters. This dataset more than doubles the total number of studied fish bone assemblages in this region.

The chapter is divided into two main halves. The first section is devoted to a description of the methods utilised in this study (section 5.1.). These include details of the osteological reference collection constructed especially for this study (section 5.1.1. and Appendix 3). The selection of zooarchaeological assemblages is then discussed (section 5.1.2.). Details are provided concerning the recording protocol used to record all the fish bone assemblages analysed in this study (section 5.1.4.), as well as the various quantification methods used to describe the data (section 5.1.5). The second section within this chapter (section 5.2.) presents the primary data results from the study of archaeological fish bone assemblages from 23 sites located in the Arabian Gulf and Gulf of Oman. Each of the sites are discussed in turn. The archaeological background to each site is first summarised, including details of recovery procedures used to collect the faunal sample, followed by information about the fish taxa, elements, and size of taxa represented. The intra-site distribution of material is commented upon if it is significant. These site entries are ordered spatially rather than chronologically for reasons which will become more apparent in Chapter 6 (sections 6.6 and 6.9).

5.1. Methods

5.1.1. Osteological Reference Collection

Desse (1995) has summarised several major difficulties which emerge when attempting to study the archaeological remains of fishes from the Arabian Gulf and Indian Ocean. One of these is the identification and taxonomy of the modern fishes, a subject already dealt with above. A further problem is access to suitable osteological comparative collections. The only osteological comparative collections in existence which have a significant component of Arabian Gulf fishes are those of Jean Desse and Nathalie Desse-Berset (CNRS

Valbonne, France), Arturo Morales (Autonoma University, Madrid, Spain), Wim Van Neer (Royal Africa Museum, Tervuren, Belgium) and Angela von den Driesch (Munich, Germany). Unfortunately no substantial collection exists in Britain, and even though the fish section in the Natural History Museum (NHM), London, has a number of specimens from the region the majority of these are unprovenanced and without associated data (i.e. no data on origin, length measurements, etc.).

In order to identify the archaeological fish remains analysed in this study it was first therefore necessary to construct an osteological reference collection of Arabian Gulf fishes. No such collection existed in the UK so it became paramount to form adequate reference material before undertaking this study. This involved a considerable amount of time spent in the field collecting specimens. Four two month fieldtrips were made to the United Arab Emirates during the spring of 1997, 1998, 1999 and 2000. Fishes were collected from two main regions: the western region of Abu Dhabi (Sila fish market, Dalma fish market and Sir Bani Yas island) and the northern Emirates (Dubai and Ras al-Khaimah fish markets). The majority of specimens were obtained from fish markets, a small number being caught by the author using hand lines on Sir Bani Yas. The recording and preparation of all specimens was carried out in the field. Various effective preparation methods have been suggested within the literature for the preparation of fish skeletons for osteological collections (e.g. Colley and Spennemann 1987; Wheeler and Jones 1989: 177-185). The present author used varying methods depending on the size of the fish being prepared. These methods are detailed in Appendix 2.

The end product of these field trips was the creation of an osteological reference collection of 215 specimens of Arabian Gulf fishes comprising a total of 51 families, 83 genera and 112 species. A complete catalogue of this collection is provided in Appendix 3.

5.1.2. Selection of zooarchaeological assemblages

An attempt was made to gather all unstudied zooarchaeological assemblages containing fish remains within the study region dating between the 5th millennium BC to the Late Islamic period. To a great extent this was determined by the availability of material, as well as the cooperation of a number of international teams of archaeologists working in the region. Most of the assemblages studied come from ongoing excavation projects and are therefore not yet published in full. A major advantage of all the studied assemblages was that they were all retrieved using similar retrieval methods. This will be discussed in more detail in the following section.

The distribution of the sites analysed in this present study are presented in Figure 10, and a list of all these is also provided in Table 4. These new sites complement our existing state of knowledge (Figure 9). The assemblage from Kuwait provides an insight into the 6th-5th millennium BC coastal communities inhabiting the mainland coast, as opposed to the later Dilmun and Hellenistic period sites known on the offshore island of Failaka (Desse and Desse-Berset 1990). Analysis of the various fish assemblages from Dosariyah (Masry 1974) provides for the first time an idea of subsistence strategies employed by broadly contemporary communities living on the Saudi Arabian Gulf coast. However, the majority of the studied assemblages come from the coastline of Abu Dhabi in the UAE. This is largely an effect of the intensity of fieldwork and excavations carried out by the Abu Dhabi Islands Archaeological Survey (ADIAS) project over the course of the past 8 years. These sites include: the late 6th millennium BC site on Merawah island (MR1), the early 5th millennium BC site on Dalma island (DA11), a series of pre-Islamic ca. 6-7th century AD sites on the islands of Sir Bani Yas and Merawah (SBY2, SBY4, SBY7, SBY9 and MR12.3), two early Islamic period sites (MR6.1 and MR6.3), and several Late Islamic period sites (MR14, MR15 and MR16) on the island of Merawah, and a Late Islamic site from the island of Balghelam (BG12), close to Abu Dhabi. The analysis of these sites plugs a gap in our existing knowledge concerning the coastal communities of the southern Gulf. A number of sites were also investigated from the northern Emirates. These include a 5th-4th millennium BC site at Umm al-Qaiwain (UAQ92-3) and an early Iron age site at Ed-Dur North (EDN). Three sites were also examined from the far north of the Oman peninsula: a 3rd millennium BC tomb (UNAR2), 2nd millennium BC tomb (SH602) and a Sasanian/Early Islamic settlement site (KU), all located in the Shimal region of Ras al-Khaimah emirate. Fish bone assemblages from sites located within the interior of SE Arabia are extremely rare. Analysis of the remains from the early-late Iron age site at Rafaq (RFQ2), located in the Wadi al-Qawr in Ras al-Khaimah emirate, provides some complementary evidence to the only other published inland site, which is the Late pre-Islamic period fort and settlement at Mleiha (Mashkour and Van Neer 1999). Finally, the analysis of the material from Kalba (KAL) represents the first fish assemblage to be examined from the UAE eastern Gulf of Oman coastline.

5.1.3. On-site recovery of vertebrate assemblages

The sediment at all the aforementioned sites consisted of fine sand, and sieving could be carried out fairly rapidly in most cases. Dry sieving was the predominant method utilised, even though it has been proven that wet sieving is less injurious to fragile fish bones (Wheeler and Jones 1989). The standard type of sieves used at the majority of these sites were 4mm mesh rocking sieves. Where different sieves or mesh sizes were used these are detailed in the appropriate site sections below. Mesh sizes finer than 4mm were only used at five sites to act as a monitor on the recovery of smaller bone fragments (KUW, DA11, SBY9, UAQ92-3 and KU). Bulk samples taken in the field were generally processed by hand using a brass 'Endecotts' 1mm mesh sieve. This study is largely concerned with the >4mm bones as these were the bones which were transported back to the UK for subsequent analysis. The 1 to <4mm fraction bones from these sites were however either partly studied (KUW), rapidly scanned in the field (DA11 and SBY9), or were completely studied (UAQ92-3), to check that large quantities of small fish were not being missed.

5.1.4. Recording protocol

All of the faunal assemblages were transported back to the UK for subsequent analysis in the Department of Archaeology at the University of York, with the exception of the Dosariyah material. This was studied during the course of a research visit in October 1999 by the author to the Archaeobiology Department of the National Museum of Natural History (Smithsonian Institution), kindly hosted by Dr. Melinda Zeder. For this research visit a substantial part of the osteological reference collection of Arabian Gulf fishes was transported to Washongton DC in two suitcases. A few specimens from this collection proved to be problematic to identify and these were then brought back to the UK on temporary loan, so that they might be checked with further comparative material.

There has been much discussion in the literature concerning which fish skeletal elements should be recorded. In this study a modification of the recording systems adopted by Leach (1986) and Wing and Scudder (1983) was utilised. The principal diagnostic elements recorded were the vomer, articular, dentary, maxilla, premaxilla, quadrate, cleithrum and post-temporal. Secondary elements which were recorded included the basioccipital, hyomandibular, and operculum. A number of other special elements were also recorded which were characteristic of certain families, genera or species. These included hyperostotic neurocranial fragments often belonging to jacks/trevallies (*Carangidae*), and occasionally to the seabream species, *Argyrops spinifer*. Neurocranial fragments belonging to sea catfish (*Ariiidae*) were also identified on the basis of their characteristic granular-like structure. Loose teeth were counted, and these largely tended to belong to seabream (*Sparidae*). Amongst these teeth, large oval molars from the posterior of the dentary and premaxilla could often be identified as belonging to the goldstriped or haffara seabream (*Rhabdosargus* sp.). Upper and lower pharyngeals were only recorded in the case of parrotfish (*Scaridae*). Other special elements recorded included otoliths, bucklers (from *Chondrichthyes*), tail spines from stingrays (*Dasyatidae*), pavement teeth from eaglerays (*Myliobatidae*), scutes (from *Carangidae*) and specialised basipterygium (from *Balistidae*). In the case of vertebrae, where possible they were divided into one of the following categories: first vertebra, abdominal vertebra, caudal vertebra, posterior (or penultimate) caudal vertebra (in the case of certain species like tuna), ultimate caudal vertebra (caudal peduncle) or indeterminate vertebra. All fragments not belonging to any of the above categories were classified as "unidentified fish bone fragments" (F). Such remains largely consisted of spine fragments and poorly preserved small fragments of other elements.

Recording of the primary elements was carried out using a diagnostic zone recording scheme (Figure 56). Fragments were only counted if >50% of one of the diagnostic zones were present (Figure 56). In the case of secondary elements, basioccipital fragments were only counted where they were >50% complete which permitted their identification (this was primarily in the case of large *Serranidae*). Hyomandibulars were only counted if any of the proximal part was present, and operculi were only counted if the small articular facet was present. Vertebrae were only recorded if >50% of the circumference of the centrum and >50% of the body was present to allow an examination of its lateral morphology.

The level of identification of fish bone fragments varies according to the morphology of the particular family, genus or species. In the case of Arabian Gulf fish bone assemblages it is evident that it is often not possible to identify material beyond the level of family or genus because of the anatomical similarity between different species within the same family or genus. In the case of the primary elements it was often possible to identify these to family, genus and occasionally to species level. In the case of secondary and special elements their level of identification depended primarily on the particular taxa being dealt with. Vertebrae were generally not identified below the level of family.

The following fields were recorded on database for each of the assemblages. Firstly, any relevant archaeological information (e.g. site code, area, context, grid square, co-ordinates, phase, etc.) was noted. Abbreviated taxonomic and element codes were then assigned for each identified bone fragment (Appendix 4). In the case of the primary elements, numerical codes were assigned depending on which zones were present. Completeness percentage scores were used for recording the proportion of the total element surviving, calculated in 20% increments. A qualitative assessment of bone texture was made to monitor general preservation conditions by scoring the bones as follows: G = good (hard sometimes shiny surface), M = medium, P = poor (soft and flaky/surface heavily concreted). Changes to the surface of the bones by burning, cut marks, teeth or signs of digestion were also noted where present.

Some measurements could be taken on more complete primary diagnostic elements following the protocols suggested by other zooarchaeologists working in the region, e.g. in the case of grouper (*Serranidae*) bones from Dalma, where those measurements recommended by Desse and Desse-Berset (1996a,b) were followed. Only in the case of dentaries (Figure 57), however, were there a sufficient number of specimens to make this worthwhile. In the case of most sites the fish remains were extremely fragmentary which meant that size estimates could only be made by directly comparing fragmentary specimens with actual modern examples from the osteological reference collection. This was usually only attempted in the case of the primary diagnostic elements (i.e. vomer, articular, dentary, maxilla, premaxilla, quadrate, cleithrum and post-temporal). Specimens were assigned to one of the following size classes: T (0-9.99cm), TT (10-19.99cm), S (20-29.99cm), SS (30-39.99cm), M (40-49.99cm), MM (50-59.99cm), L (60-69.99cm), LL (70-79.99cm), VL (80-89.99cm), VVL (90-99.99cm), XL (100-109.99cm), XXL (110-119.9cm) and XXXL (>120cm). In the case of all vertebrae (including those in the "unknown fish"category) which were complete enough, the maximum width of the diameter of the centrum was recorded to the nearest millimetre using digital callipers (Figure 57). The numbers of small fish recovered on archaeological sites in this region are probably grossly underestimated due to a combination of factors like poor preservation and recovery. There is also the inherent difficult of identifying small perciform vertebrae. It was therefore felt that such an approach would at least give some idea of the proportion of the assemblage comprising small "unidentified" fish, even if they could not be more precisely identified.

All of the above data were recorded onto a relational database using Microsoft Access 97. Subsequent analysis of the data was carried out using Microsoft Excel 97. The bone assemblages are all (with the exception of that from Dosariyah) archived in the author's laboratory in the Department of Archaeology at the University of York. An electronic archive of all the data analysed in this study is maintained by the author (Microsoft Word 97, Microsoft Access 97 and Microsoft Excel 97 format files).

5.1.5. Quantification methods

Four different methods were used to quantify the fish bones from each site: the total number of identified specimens (NISP), minimum number of individuals (MNI), bone weight, and percentage sample presence.

The total number of identified specimens (NISP) was calculated using the above protocol. Unidentified fragments, referred to in the tables as "unknown fish", usually consisted of very small pieces of fish spine or other non-diagnostic skeletal elements that were too fragmentary to identify.

Minimum number of individual (MNI) counts were calculated at the context level for the following elements: vomer, articular, dentary, maxilla, premaxilla, quadrate, hyomandibular and first vertebra. MNI values were calculated taking the highest left or right value of a particular element within each context with no reconstruction for pairs. Where a context did not contain any of these elements a score of 1 was assigned as its MNI value, working on the assumption that all of the bone fragments present may have belonged to the same individual. Total MNI counts presented for each site in the summary tables therefore represent aggregated MNI totals of all the separate contexts.

The third method used to quantify the remains was to weigh all the bone fragments. The weight of every bone fragment was measured using a digital balance to the nearest 0.01g.

Finally, the "percentage sample presence" or "relative frequency of fish taxa" method was also used to examine the assemblages (following A.K.G.Jones, cited in O'Connor 1989: 196). This is based upon the number of times a particular taxa occurs in all the studied contexts which have bones which can be identified to family, genus or species level. Thus, if groupers (*Serranidae*) occur in 5 out of a total of 10 contexts with identifiable fish remains, then it scores 0.50 (i.e. 50%).

The various methods used to quantify abundance of fish bones all have their inherent problems which have been much discussed in the literature, and there is no point reiterating all these here. One of the advantages of the percentage sample presence method is that it partly overcomes the problem of "visibility" between different taxa. Whilst some families and species may be reliably identified and distinguished by a number of different elements, others may be less easily recognised. This method also counteracts the swamping of the data by 100s of specimens of a species in one particular layer thereby artificially inflating its relative importance. A major problem which remains, however, is the differential destruction of fish bone remains, which means that some fish species and particular anatomical elements may be better or less well preserved than others. This means that this latter method probably gives a better idea of the occurrence of different taxa at the various sites.

5.2. The zooarchaeological assemblages

This section provides a description of each of the archaeological sites analysed in this study, along with the results obtained from the analysis of each assemblage.

5.2.1. Site H3, As-Sabiyah, Kuwait (KUW)

Site H3 is located at 48°09'02"E, 29°38'30"N on Jazirat Dubaij, a 4km long bedrock promontory extending westwards from the Jal Az-Zor escarpment situated in the Sabiyah region on the north coast of Kuwait Bay (Figures 10 and 58). The site was first discovered by Dr. Fahad al Wohaibi, the director of the National Museum of Kuwait. Excavations at the site during 1998-99 by Dr. Harriet Crawford and Dr. Robert Carter (Institute of Archaeology, University College, London), in conjunction with colleagues from the National Museum of Kuwait, have identified an Ubaid 2/3 period coastal site (Carter et al. 1999). The site consists of a number of well preserved stone structures with up to a metre of deposits, abundant pottery and lithics and evidence for the manufacture of shell beads (Carter 1999). At least five separate stone structures can be seen at the surface within an area of about 100 x 80m (Figures 59-60). Three trenches were made on the excavation: area A (on top of the mound), area B (on the west side of the mound) and area F (a deep sounding adjoining the SE corner of area A, at the edge of a fox-hole dug during the Gulf War).

A small number of fish bones were recovered by hand from nine different contexts: Area A: 1003, 1006, 1008, 1010, 1011, 1017, 1018 and 1019; Area B: 2000. Most of the bones were recovered by dry sieving using a 4mm mesh from nineteen different contexts: Area A: 10, 1003, 1004, 1006, 1008, 1009, 1011, 1017, 1019; Area B: 2, 2000, 2001, 2002, and 2005; Area F: 54, 55, 58, 59, 60. A number of bulk sediment samples were also taken. These were processed using a combination of flotation (>250 micron and >1mm flot) and wet screening (>1mm residue), with a modified version of the Ankara water-separation machine (French 1971). These samples were usually 30 litres or more in volume. Once air-dried the wet screened residues were dry sieved using a >2mm mesh sieve. All of the >2mm residues, but only a proportion of the 1-2mm residues, were scanned for finds. Very few identifiable fish remains were recovered from the >1mm(<2mm) mesh residue. The >2mm(<4mm) fraction consisted entirely of vertebrae from very small fish and occasional seabream teeth. One of these samples from context 55 was scanned to assess the remains.

Non-fish remains recovered from the site included small quantities of sheep/goat (both sheep and goat being present), as well as a few fragments of cattle (Patrick Hunter, pers.comm.). However, fish remains formed 58% of the total faunal assemblage by weight (1689g of fish bone versus 1,221g of mammal bone, of which only 253g were identifiable mammal bone fragments). A single chela from a swimming crab (*Portunus*) was also noted (Peter Hogarth, pers.comm.).

5.2.1.1. Site H3 – Hand collected bones

A total of 149 fish bone fragments (66g) was recovered by hand from the excavation (Table 33). Out of these, 74 (50%) were identifiable to class or family. A total of seven families including at least five genera were represented. These included: requiem sharks (*Carcharhinus* sp.), sawfish (*Pristidae*), unknown shark or ray (*Chondrichthyes*), grouper (*Epinephelus* sp.), groupers (*Serranidae*), jack (*Carangoides* sp.), jacks (*Carangidae*), emperors (*Lethrinus* sp.), haffara/goldlined seabream (*Rhabdosargus* sp.), seabream (*Sparidae*) and tuna/mackerel (*Scombridae*). Caudal vertebrae of requiem sharks formed the bulk of the remains.

Hand recovered fish bones were recovered from 9 different archaeological contexts (Appendix 5 - Table 169). The majority of the identifiable material, including the requiem shark caudal vertebrae, came from area A, context 1019. Groupers, emperors and seabream were all represented by anatomical elements from both the skull and body of the fish, whilst other taxa were only represented by vertebrae (Table 34).

5.2.1.2. Site H3 - >4mm sieved bones

A total of 6451 fish bone fragments (1623g) was recovered by >4mm mesh sieving on the excavation (Table 35). Out of these, 1018 (16%) were identifiable to class, family, genus or species level. A total of ten families including at least fourteen genera were represented. These included: requiem sharks, sawfish, eaglerays (*Myliobatidae*), unknown shark or ray, sea catfish (*Ariidae*: *Arius* sp.), flatheads (*Platycephalus* sp.), groupers, scads (*Decapterus* sp.), queenfish (*Scomberoides* sp.), jacks, emperors, seabream (*Acanthopagrus* sp.), king soldierbream (*Argyrops spinifer*), haffara/goldlined seabream, indeterminate seabream and tuna/mackerel. The most frequent families represented were requiem sharks, sea catfish, groupers, jacks and primarily seabream.

The condition of the bones varied between contexts. Generally the bones were recorded as being either medium to poorly preserved. Many fragments were difficult to identify because of heavy salt and carbonate concretions across their surfaces. This generally hindered the identification process. The poorest preserved material was recovered from area A - contexts 1003, 1017 and 1019, whilst the remainder was fairly similar in condition. About 57% of the studied contexts contained low numbers of burnt fish bone fragments, suggesting that some fish may have been cooked on open fires. None of the bones showed any traces of butchery marks but some of these may have been obscured by the aforementioned concretions.

Fish bones were recovered from 19 different archaeological contexts (Appendix 5 - Table 170). The following layers contained the richest amount of material: area A: contexts 1017 and 1019; area F, contexts 55, 58, 59 and 60. Quantification was carried out using four methods: NISP, MNI and weight (Appendix 5 – Tables 170-173) and % presence (Table 36). These all demonstrated the relative importance of requiem sharks, sea catfish, groupers, scads/jacks and seabream.

5.2.1.3. Site H3 - Elements represented

Requiem sharks were represented predominantly by vertebrae, although a single tooth fragment was also recorded in context 55 (Table 37). The remains of sawfish (*Pristidae*) similarly consisted of calcified caudal vertebrae. Eagleray (*Myliobatidae*) remains all comprised fragments of their characteristic pavement teeth. A notable feature of the H3 fish bone assemblage was the excellent preservation of 65 sea catfish (*Arius* spp.) otoliths (Figure 62). These varied in size from some quite small examples to some quite large specimens, which must be from mature adult fish (Figure 63). The majority of them however clustered between a maximum width of 10-12 mm and 8-10mm in height. This fish was also represented by a small number of neurocrania fragments which could be identified on the basis of their characteristic granular texture. A few vertebrae were also recognised as belonging to sea catfish. These were surprisingly few in number compared to the number of fish represented by the otoliths. This bias is probably due to differential survival and preservation, as sea catfish otoliths are quite bulbous in shape and perhaps survive better than other skeletal elements. Flatheads (*Platycephalidae*) were represented by both cranial elements and vertebrae. Groupers (*Serranidae*) were represented by both cranial elements (Figure 63) and vertebrae. The larger grouper bones all belonged to the genus, *Epinephelus* sp. Jacks (*Carangidae*) were represented by the genera, *Carangoides*, *Decapterus* and *Scomberoides*. *Carangoides* was represented by both cranial elements and vertebrae, whilst layer 55 in area F contained a concentration of 21 first vertebrae belonging to *Decapterus*. Layer 59 in area F contained three abdominal vertebrae from a queenfish (*Scomberoides* sp.). Emperors (*Lethrinus* sp.) were represented by both cranial elements and vertebrae. Seabream (*Sparidae*) were represented by both cranial elements (Figure 64) and vertebrae. Tuna/mackerel (*Scombridae*) were represented almost entirely by vertebrae, with the exception of a single dentary fragment in area F – context 55. Morphologically the vertebrae bore a good resemblance to the tuna genera, *Euthynnus* and *Thunnus*. No elements could definitively be attributed to *Rastrelliger* or *Scomberomorus*.

Of particular interest was the fact that four contexts in area A contained articulated segments of fish, usually consisting of a sequence of two or more vertebrae. These were cemented in place by some of the aforementioned carbonate concretions. Two articulated caudal vertebrae from a jack (*Carangidae*) were found in context 1003. These were from a small fish as the maximum width of the centrum was only 4mm. Three articulated shark/ray (*Chondrichthyes*) caudal vertebrae were found in context 1006. These were also small in size (max. width of centrum = 4mm). In context 1017 a number of articulated segments were discovered. These included groups of four and two articulated caudal vertebrae from sharks/rays (*Chondrichthyes*), the maximum width of the centrum of all the vertebrae being 4mm. Two articulated abdominal vertebrae were also recovered from seabream (*Sparidae*). These were from small fish judging from the relative size of the vertebrae (max. width of centrum = 6mm). Context 1017 also included nine other articulated caudal and posterior caudal vertebrae from unknown fish. These were all from small-sized fish (max. width of centrum between 4-6mm). Context 1019 contained the greatest number of articulated fish. Thirteen pairs of articulated caudal vertebrae from requiem shark (*Carcharhinus* sp.) were noted. The size of these vertebrae varied between 7-9mm. Three smaller shark/ray (*Chondrichthyes*) articulated caudal vertebrae were also present (max. width of centrum = 3mm). Two pairs of articulated vertebrae belonging to jack (*Carangoides sp.*) were recorded (max. width of centrum = 7mm). Three pairs of articulated posterior vertebrae, plus two pairs of articulated posterior and ultimate vertebrae could only be identified to the level of jack family (*Carangidae*). These were all from small fish (max. width of centrum between 4-7mm). Two larger articulated abdominal vertebrae belonging to tuna were also noted (max. width of centrum = 13mm). Finally, a pair of three articulated posterior caudal vertebrae from an unknown fish species was recorded (max. width of centrum = 6mm). Most of the articulated fish remains were from quite small-sized fish, with the exception of the tuna abdominal vertebrae in context 1019. It seems likely that some of these fish may have been discarded in a fairly complete state within these contexts.

5.2.1.4. Site H3 - Size of fish

The diagnostic elements which could be assigned to particular size classes mostly came from small-medium-sized fish, with comparatively few large or very large specimens (Table 38). Out of these recorded diagnostic elements, 58% were from fish smaller than 30cm in length, 78% were less than 40cm and 92% were less than 50cm in length. Flatheads ranged between 30-50 cm, *Carangoides* between 50-70cm, groupers between 20-90 cm (most of them being between 30-50 cm), emperors between 20-50 cm, seabream between 20-50 cm, and tuna between 40-50 cm. The dentary, identified as belonging to tuna came from a relatively small-sized individual between 40-50cm. This may belong to one of the two common smaller species of tuna occurring in the region. The kawkawa/eastern little tuna, *Euthynnus affinis*, is often around 60cm in fork length up to a maximum of about

100cm. The other common tuna species is the longtail tuna, *Thunnus tonggol*, which commonly has a fork length of about 70cm up to a maximum of about 130cm.

Analysis of the size of the vertebrae (Table 39 and Figure 65) confirmed the picture obtained from the diagnostic elements, namely that most of the fish were small-medium in size with only a few larger specimens. The only taxa with large vertebrae were sawfish, groupers and tuna.

However, a scan of the >1mm to <4mm fraction bones from context 55 revealed that large quantities of small fish were present in this context (Figure 66). These vertebrae largely consisted of small perciform vertebrae. This indicates that small fish played an important role at the site.

5.2.1.5. Site H3 - Summary

Requiem sharks (*Carcharhinidae*), sea catfish (*Ariidae*), groupers (*Serranidae*), scads/jacks (particularly *Carangoides* and *Decapterus* spp.) and seabream (particularly *Argyrops spinifer* and *Rhabdosargus* spp.) were all important fish families at site H3 in Kuwait. The presence of small quantities of tuna was noted. Most of the fish represented were small to medium-sized individuals less than 50cm in length. The only large fish present were groupers (*Epinephelus* spp.) and a type of jack, *Carangoides* sp. Selective fine sieving carried out at the site demonstrated that small fish were abundant in some contexts.

5.2.2. Dosariyah, Eastern Saudi Arabia (DOS)

The Dosariyah site is located at 49°44'39"E, 26°55'18"N in the al Dikaka area, 12km south of the coastal town of Jubail in the Eastern Province of Saudi Arabia (Figures 10 and 67). The site itself is located one and a half kilometres inland from the present day Gulf coast. It was first discovered by Burkholder (1972) who noted that it consisted of two exposed areas, the larger of which was over 100 metres long, situated between white sand dunes (Figure 68). In total the site covered an area of approximately 1.6km. More than 1,000 painted early-middle Ubaid type sherds were found on the surface, along with a number of unpainted, straw-tempered coarse red sherds. This makes it the largest and most extensive of the Ubaid coastal settlements in northeastern Arabia. The lithics assemblage recovered from the surface included large numbers of flint awls, scrapers, knives, flakes and arrowheads. These all typologically resembled Qatar Group D. A number of polished stone celts and grinding stones were also collected as well as a pressure-flaked knife, two beads and a few obsidian blades. Fragments of plaster, some with reed-impressions, suggested the remains of *barasti*-like houses built of reed and plaster. It has been pointed out by a number of authors (Burkholder and Golding 1971; Potts 1990a: 44) that one plaster fragment discovered at a height of 5.5m above the present day sea-level may indicate a possible change in sea-level which may have affected the site. Masry (1974, 1997) subsequently noted the presence of a small mound nearly 3 metres high at the centre of the site. The surface of the site was packed with shell fragments, which in some places were up to 30cm deep. Large quantities of painted and plain Haji Mohammed-Standard Ubaid pottery were recovered. A gridded surface collection was carried out and this collected a number of stone implements including side scrapers and tanged-barbed arrow-heads made of tabular flint, hand axes, grinding stones and many lime plaster fragments. Four excavation trenches were made. Further details concerning the stratigraphic sequence and the radiocarbon dates from the site are provided in Appendix 6. Unfortunately precise details of the retrieval methods used to recover the faunal remaains from these trenches is not available. It seems likely that the surface material was largely collected by hand though and that some sieving was carried out during the excavaton of trenches, judging by the relative size of bone fragments. This may have been using a ca. 5mm mesh.

Significant quantities of fish bones were recovered in trenches 1, 5, 6 and 7 at Dosariyah during Abdullah Masry's excavations in 1968. All the faunal material was transported back to the USA for analysis, and subsequently Dr. Melinda Zeder (then of the Department of Anthropology in Michigan, now of the National Museum of Natural History, Smithsonian Institution, Washington DC) undertook analysis of the mammalian remains from the site (Masry 1974, 1997). The present author made a one week research visit to Washington DC to study this collection in October 1999.

Mammalian remains identified by Zeder included cattle, sheep/goat, gazelle, equid, canid and hare (Masry op. cit.). Caprids were the most numerous mammal at the site, based on bone counts. However, Zeder noted that the ratio of fish bone to mammal bone was 2 grams fish to 1 gram mammal, suggesting that fish played an important role in the subsistence of the inhabitants of Dosariyah. At Dosariyah 60% of the weight of the assemblage was comprised of fish remains (Masry 1974, 235). This was similar to the nearby site of Abu Khamis where 85% of the faunal assemblage consisted of fish remains. Other non-fish remains identified at Dosariyah included three chelae from swimming crabs, *Portunus* (Peter Hogarth, pers. comm.).

5.2.2.1. Dosariyah - Surface deposits (DOS-S)

A total of 172 fish bone fragments were collected from the surface of Dosariyah, of which 141 (92%) were identifiable to at least family, genus or species level (Table 40). Six families were represented, including at least seven genera. The following families were present: requiem shark (*Carcharhinidae*), sawfish (*Pristidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), seabream (*Sparidae*) and tuna (*Thunninae*). The most frequent families represented were tuna followed by requiem sharks, only small quantities of other fishes being present. Most of the remains were vertebrae, although some cranial elements from groupers, jacks and seabream were noted (Table 41). The size of these diagnostic cranial elements indicated that small seabream between 10-40cm were present, as well as large jacks (*Carangoides* sp.) between 50-90cm and groupers (*Epinephelus* sp.) between 40-90cm (Table 42). Analysis of the size of vertebrae in surface deposits at Dosariyah also indicated that large requiem sharks, sawfish and tuna were also present (Table 43 and Figure 69). The fact that no vertebrae smaller than 12mm diameter were recorded suggests that there has been a recovery bias in the collection of this material. Preservational biases may also partly account for the numerous shark vertebrae and tuna posterior caudal vertebrae. The drum-like shape of shark vertebrae and the density of tuna tail vertebrae may have aided their preservation in the surface deposits.

5.2.2.2. Dosariyah - Trench 1 (DOS-T1)

A total of 2720 fish bone fragments were collected from trench 1 at Dosariyah, of which 1092 (40%) were identifiable to the level of family, genus or species (Table 44). Thirteen families were represented, including at least fourteen genera. The following families were present: requiem sharks, sawfish, stingrays (*Dasyatidae*), rays (*Rajidae*), eaglerays (*Myliobatidae*), sea catfish (*Ariidae*), groupers, jacks/trevallies, emperors (*Lethrinidae*), seabream, parrotfish (*Scaridae*), barracuda (*Sphyraenidae*) and tuna/mackerel (*Scombridae*). The most frequent families represented were seabream with only smaller quantities of other taxa being present (Table 45, and Appendix 5 – Tables 174-6). Seabream were mostly represented by cranial elements, relatively few vertebrae being recorded (Table 46). *Rhabdosargus* and *Argyrops spinifer* were the common genera of seabream present. Examination of the size classes of the diagnostic elements revealed that these nearly all came from small individuals between 10-30cm in length (Table 47). The only larger fish present were a large grouper (90-100cm), medium-sized (50-60cm) and large-sized (90-100cm) parrotfish (*Scaridae*), and a large tuna (80-90cm). Analysis of the size of vertebrae broadly confirmed this picture but demonstrated that medium to large sized requiem sharks and sawfish were also present (Table 48 and Figure 70). The fact that some quite small vertebrae were present suggests that it is likely that dry sieving, perhaps using a ca. 5mm mesh was used during the excavation. As in the case of the general surface material collected at the site, much of the shark and eagleray material came from the surface layers. Other taxa were fairly evenly represented through the different layers.

5.2.2.3. Dosariyah - Trench 5 (DOS-T5)

A total of 243 fish bone fragments were recovered from trench 5, of which 112 (46%) were identified to the level of family, genus or species (Table 49). Six families were represented, including at least eight genera. The following families were present: sawfish, groupers, jacks/trevallies, emperors, seabream and tuna. Seabream and tuna were among the most frequent families represented, the former again being mostly represented by cranial elements, with relatively few vertebrae being noted (Table 50). The few bones from jacks/trevallies and emperors were also all cranial elements. In the case of groupers and tuna, both cranial and trunk elements were present. *Acanthopagrus*, *Argyrops spinifer* and *Rhabdosargus* were all represented amongst the seabream. Cranial elements as well as a caudal peduncle were identified from kawakawa/little eastern tuna (*Euthynnus affinis*). Most of the remains were from small fish sized between 10-30cm (Table 51). The only larger fish present were groupers sized between 60-90cm, jacks sized between 80-100cm and two tuna, sized 80-90 and 100-110cm respectively. Closer examination of the size of vertebrae showed that most of them belonged to tuna, with large sawfish and shark also present (Table 52 and Figure 71). The various taxa were fairly evenly represented between different layers, although most of the material came from context 3 in the lowermost deposit (Appendix 5 – Tables 177-9).

5.2.2.4. Dosariyah - Trench 7 (DOS-T7)

A total of 1277 fish bone fragments were recovered from trench 7, of which 688 (54%) were identified to the level of family, genus or species (Table 53). Ten families were represented, including at least fourteen genera. The following families were present: requiem sharks, eaglerays, sea catfish, flatheads (*Platycephalidae*), groupers, jacks/trevallies, emperors, seabream, parrotfish and tuna. Seabream appear to have been the most frequent family exploited, followed by groupers and jacks/trevallies (Table 54). Only a very small quantity of tuna was noted. Both cranial and trunk (vertebrae) elements were recorded from all the major families (Table 55). *Carangoides* was the most commonly observed genus amongst the jacks/trevallies, followed by *Gnathanodon speciosus* and *Trachinotus*. Seabream genera included *Acanthopagrus*, *Argyrops spinifer* and *Rhabdosargus*, the latter genus being the most common. Analysis of the size class data from diagnostic elements (Table 56) suggested that the species of flathead present was between 40-50cm, meaning that it probably belongs to the Indian flathead, *Platycephalus indicus*. Groupers were sized between 30-90cm, most falling in the upper part of the range and belonging to *Epinephelus* sp. The jack/trevally diagnostic elements all originated from medium to large sized fish between 50-120cm. Most of the emperor and seabream diagnostic elements came from small fish sized between 10-30cm. Two parrotfish (*Scaridae*) dentaries were noted from medium-sized 50-70cm individuals. An articular from a kawakawa/little eastern tuna (*Euthynnus affinis*) came from a 70-80cm individual. The size of the fish vertebrae in trench 7 confirmed the presence of large groupers, jacks (including the genus *Carangoides*), small seabream and medium-sized tuna (Table 57 and Figure 72). Most of the bones came from contexts 1, 2 5 and 7 (Appendix 5 – Tables 180-182). As in the case of trench 1, the surface deposits largely consisted of eagleray teeth fragments. Groupers and seabream were fairly evenly distributed between different layers.

5.2.2.5. Dosariyah - Summary

A contrasting picture was obtained from the different excavation areas at Dosariyah. Whereas the surface deposits were largely composed of bones from tuna and requiem sharks, seabream dominated in trench 1 with relatively small amounts of tuna, trench 5 contained both seabream and tuna in moderate quantities, and trench 7 was largely comprised of seabream, groupers and jacks/trevallies. Although the seabream were mostly small fish (10-30cm), some quite large individuals of groupers, jacks, parrotfish and tuna were also noted. There was a hint in the general surface deposits as well as within trenches 1 and 7 that sharks and eaglerays were more common during the later occupation phase at the site.

5.2.3. Site DA11, Dalma island, Abu Dhabi emirate, UAE (DA11)

Dalma is an island located at 52°18'37"E 24°30'38"N, some 29.5 kms north-west of Sir Bani Yas and 80 kms from the eastern coast of Qatar in the western Abu Dhabi region of the UAE (Figures 10 and 73). The island measures 9 kms from north to south and 5 kms from east to west, rising to 98m at its centre. Originally to the south of Dalma a smaller island was located, which is now joined to the main island by a modern landfill peninsula. Dalma has a modern population of some 6-7,000 inhabitants. A permanent population existed on the island during the more recent historical period supported by the presence of freshwater wells. The main settlement, also called Dalma, is located towards the southern tip of the island. The island was traditionally an important centre for the pearl trade (Lorimer 1908-15). An initial brief archaeological reconnaissance of Dalma was carried out by Harter et al. (1979). In 1992 the Abu Dhabi Islands Archaeological Survey (ADIAS) carried out the first comprehensive field survey of the island (King 1998). This work demonstrated a much longer history of settlement of the island than had previously been suspected. The discovery of 'Ubaid pottery on the surface of site DA11 showed that settlement on the island dated as far back as the 5th millennium BC. The site lies within the compound of the Jama^{c}iyya nahda li-imrat al-Zubyaniyya (the Abu Dhabi Women's Association) in Dalma town. Excavations at the site between 1993-4 revealed that settlement traces covered an area of about 175 x 150 m. Two sample transects were placed across the site, and the top ca 5cm of the surface was systematically sieved by each metre square through a 4mm mesh (Shepherd et al. forthcoming). The particular concentrations of bone, flint, pottery, shell and various small finds like beads in the NW corner of the compound assisted with the placement of two test trenches (Figure 74). These established that archaeological deposits were at least a metre to a metre and a half in depth (Flavin and Shepherd 1994). The stratigraphic sequence revealed by this work is summarised in Figure 75. Subsequently a short fieldwork season directed by the author and Joe Elders in 1998 continued the excavation in both these test trenches. Additional stratified material for environmental analysis as well as radiocarbon samples were taken. This work led to the exciting discovery of earlier phases of occupation and traces of two house structures (Beech and Elders 1999; Elders and Beech 1998). Further details of the stratigraphy of the site, including the radiocarbon dates, are provided in Appendix 6.

Large quantities of fish bones were recovered during the initial sieving of the surface layers, as well as during the excavation of the two test trenches. This present analysis is concerned with the material excavated during the 1993-4 seasons. Retrieval of bones was carried out using 4mm mesh rocking sieves.

Non-fish remains identified at Dalma included sheep/goat, gazelle, dolphin/porpoise, dugong, turtle and Socotra cormorant (Beech 2000). However, fish remains formed the bulk of the faunal assemblage by weight (91%), followed by marine turtle (5%), terrestrial mammal (3%), marine mammal, crabs and bird (all <1%).

5.2.3.1. Dalma - Fish taxa represented

A total of 17,858 fish bone fragments were recovered from the site during the 1993-4 seasons, of which 4,655 (26%) were identified to family, genus or species level (Table 58). Sixteen families were represented, including at least 23 genera. The following families were present: thresher sharks (*Alopiidae*), requiem sharks (*Carcharhinidae*), hammerhead sharks (*Sphyrnidae*), sawfish (*Pristidae*), eaglerays (*Myliobatidae*), sea catfish (*Ariidae*), needlefish (*Belonidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), parrotfish (*Scaridae*), barracudas (*Sphyraenidae*) and tuna/mackerel (*Scombridae*). Requiem sharks, needlefish, groupers, jacks, emperors, seabream and tuna all seemed to be important groups of fish which were exploited (Tables 59-60).

Genera represented amongst the jacks included *Carangoides*, *Gnathanodon speciosus*, *Megalaspis cordyla* and *Scomberoides*. Seabream were mostly represented by *Rhabdosargus* followed by *Acanthopagrus*, with only small quantities of *Argyrops spinifer*. Most of the scombrid remains belonged to the kawakawa/little eastern tuna, *Euthynnus affinis*, with small quantities of longtail tuna, *Thunnus* sp., and spanish mackerel, *Scomberomorus* sp.

The surface layers contained mostly vertebrae belonging to sharks, as well as small quantities of needlefish, grouper, jack, emperor, seabream and tuna (Table 59). The earliest phases contained larger quantities of material. Taxa were fairly evenly represented, although the remains of *Chondrichthyes* were less frequent, and needlefish were more common in the lower deposits (phases 2-4). Seabream was also better represented in phases 1-3 than in the surface deposits. Tuna which only formed 1% or less of the total identified remains in the surface layers and phases 1 and 3, occurred in greater numbers in phases 2 and 4 where it represented 13% and 8% of the total identified remains. This can be more clearly seen in Figure 76. The few specimens of Spanish mackerel (*Scomberomorus* sp.) noted all came from one of the earliest layers in phase 4, context 16. The richest fish layer at the site was the deepest layer, context 40 in phase 4, which was the primary refuse level immediately overlaying the ground surface outside the two houses discovered during the 1998 excavations (Appendix 5 – Tables 183-5).

5.2.3.2. Dalma - Elements represented

Sharks, sawfish and rays were represented almost entirely by vertebrae, although phase 3 (contexts 13, 14 and 32) contained a small concentration of eagleray (*Myliobatidae*) teeth fragments (Table 61). Needlefish, groupers jacks, emperors, seabream, barracuda and tuna were all represented by both cranial elements and vertebrae. Groupers were particularly well represented by cranial elements, first vertebrae and abdominal vertebrae, with low numbers of caudal vertebrae. This may indicate a bias towards the heads of these fish being removed, the remainder of the fish ending up elsewhere. In the case of tuna, however, there were comparatively few cranial elements as opposed to vertebrae. Examining the anatomical elements from the major fish families present at Dalma in the various site phases revealed broadly similar trends throughout the sequence (Table 62). This suggests that either similar processing methods were being used for fish like groupers and tuna, or perhaps that differential preservation has similarly affected these particular elements.

5.2.3.3. Dalma - Size of fish

Analysis of the size of the diagnostic elements from Dalma demonstrates that both small and large fish were present in all phases (Table 63 and Figure 78). Needlefish ranged from 40-80cm in size, groupers from 30-90cm, jacks/trevallies from 30-90cm, emperors from 10-40cm, seabream from 10-90 cm (most being between 10-40cm), parrotfish from 30-50cm, and tuna from 70-80cm.

Closer examination of the numerous grouper diagnostic elements confirmed that most of them came from individuals sized between 50-80cm (Figure 79). As a considerable number of grouper dentaries were complete enough to take measurements following those recommended by Desse and Desse-Berset (1996a), measurement 1 was examined to check the original size of the fish in comparison with a series of modern grouper dentaries in the author's reference collection (Figure 80). When all the examples in the collection are measured including both *Cephalopholis* and *Epinephelus* genera, it can be seen that there is a good correlation between the measurement and the length of the fish (Figure 80, top). The r-squared value is even higher if one only includes *Epinephelinae*, and excludes *Cephalopholis* which just lies outside the 95% confidence boundary values. Using the regression formula derived from the modern dentaries and plotting the archaeological specimens on the same curve, it can be seen that groupers ranged in size from around 42-87 cm in size (Figure 80, bottom). This confirmed the trend observed in the classification of other diagnostic elements into size classes.

Closer inspection of the size of all the vertebrae from Dalma demonstrates the importance of smaller fish at the site. Large numbers of small vertebrae belonging to sharks/rays/skates (*Chondrichthyes*), needlefish (*Belonidae*) and seabream (*Sparidae*) were observed (Table 64 and Figure 77). However, some of the vertebrae did also come from larger fish. Four particularly large caudal vertebrae from a thresher shark (*Alopiidae*) were recovered in the surface layers. The general size of some of the requiem shark vertebrae indicated that some were probably from medium-large sized individuals. Examination of the size distribution of grouper vertebrae confirmed that mostly larger fish were present. In the case of jacks/trevallies, mostly small to medium sized fish were recorded. The barracuda vertebra was from quite a small individual. Tuna vertebrae came from medium to large individuals. The Spanish mackerel vertebrae all came from a medium-sized individual.

5.2.3.4. Dalma - Summary

Requiem sharks, needlefish, groupers, jacks, emperors, seabream and tuna all seemed to be important groups of fish exploited at Dalma. Both small and large fish were caught, with a particular reliance on smaller seabream (10-40cm) and large groupers (50-80cm). Fishing for larger pelagics like tuna and Spanish mackerel appeared to be more common during the early phases at the site. The surface layers, as at Dosariyah, contained mostly vertebrae from sharks.

5.2.4. Sir Bani Yas island, Abu Dhabi emirate, UAE

The island of Sir Bani Yas lies at 52°36'21"E 24°19'46"N, 9 kms due north of Jebal Dhanna and 235 kms west of Abu Dhabi, the capital of the UAE and of the Emirate of the same name

(Figure 10). The island is 17.5 kms from north to south and 9 kms from east to west, with a range of bare volcanic mountains rising in the central area to a maximum height of 139 m (Figure 81). Sir Bani Yas island is currently utilised as a private residence for the ruler of the UAE, President His Highness Sheikh Zayed bin Sultan al Nahyan. The island is used as a major wildlife sanctuary,.and access is restricted to invited guests. There appears to be no permanent water supply on the island at the present time, and only occasional rain pools seem to have existed. The coastal plain on all sides of the island is now heavily planted with trees. This has taken place in the last 20 years as a result of the ruler's interest in afforestation. There are now numerous enclosures around the planted areas, both to protect the trees from the herds of gazelle, oryx and other animals introduced by the President and also to contain other animals including llamas, ostrich, rhea and numerous others.

Although a brief archaeological survey of the western Abu Dhabi region was carried out in 1983 by Vogt et al. (1989), it was not until the 2-3 May 1991, when Carolyn Lehmann of the Emirates Natural History Group visited Sir Bani Yas island that the presence of several archaeological sites were noted. She observed significant quantities of potsherds in the area of the llama pens on the western side of the island, along with an "old house", which subsequently became known as site SBY3 (Lehmann 1991). In 1992 the Abu Dhabi Islands Archaeological Survey (ADIAS) carried out the first comprehensive field survey of the island (King 1998). This identified more than 30 sites ranging in date from the Late Stone Age to Islamic periods. The most significant group of sites were clustered on the eastern side of the island (Figure 81). Sites SBY2 lay furthest inland about 2km from the present day sea level. Sites SBY3-9 are situated on the coastal plain in the area north of Jabal Buwaytir, in the neighbourhood of al-Khawr, at the foot of the last ridge descending eastwards from the central mountains ridge. These sites all turned out to be related in that they all proved to belong to a community of Nestorian christians inhabiting the island during the 6-7th century AD (King 1997, 1998). The central site (SBY9) proved to be a church enclosed within a monastic complex, surrounded in its vicinity by a number of courtyarded villas (SBY2, SBY3, SBY4 and SBY7). All the excavated sediment from these sites were 100% sieved using 4mm mesh sieves, with important stratigraphic layers being monitored by sieving using 1mm mesh hand sieves.

5.2.4.1. Site SBY2, Sir Bani Yas island (SBY2)

Site 2 (SBY2.1 and SBY2.2) was a large, low and irregular mound which lay about 50 m west of site 1 (a concentrated 6^{th}-7^{th} c. AD pottery scatter) on Sir Bani Yas island (Figure 81, no. 2). The site extended over an area of ca 50 m from north-south, 34 m east-west and was 3 m in height. The mound sloped down sharply to the east and south, and more gently to the north. A number of wall traces were initally visible, but the plan of the building was not readily discernible (SBY2.2). Some masonry was cut and bonded with a grey/brown sandy mortar, and there were traces of smooth light grey plaster c. 1cm thick. The mound seemed to form a rough, raised rectangle and judging by the amount of rubble, it was a building of some size. The mound is hollow in the centre with a dump of stone and sand to west (SBY2.1). Pottery was found at the site and there was a general scatter of finds and stone well away from site in all directions. Subsequent excavation of the site by Salvatore Garfi for ADIAS, confirmed the 6-7^{th} c. AD date and recovered small quantities of fish bones from a number of stratified layers relating to the building (Figure 82). The only non-fish remains recovered from the site was a chela from a small xanthid crab (Peter Hogarth, pers. comm.).

A total of 180 fish bone fragments were recovered during the excavation, out of which 10 (6%) could be identified to family or genus level (Table 65). The material was very poorly preserved which accounted for the low percentage of bones which could be identified. The bones were extremely fragile and had suffered extensive salt damage. Most of the fish remains came from context 50, a layer contemporary with the occupation of the building (Appendix 5 - Tables 186-8). A total of five families were represented, and these were as follows: sea catfish (*Ariidae*), needlefish (*Belonidae*), groupers (*Serranidae*), emperors (*Lethrinidae*) and seabream (*Sparidae*). Sea catfish was represented by a distinctive neurocranial fragment, grouper by only cranial fragments, needlefish and emperors by vertebrae, and seabream by both cranial elements and vertebrae (Table 66). Those diagnostic elements which could be attributed to particular size classes suggested that the sea catfish was from a medium-sized individual between 50-60cm, whilst the groupers were all small, between 20-40cm (Table 67). The size of the vertebrae indicated the general predominance of smaller fish (Table 68 and Figure 83).

5.2.4.2. Site SBY4, Sir Bani Yas island (SBY4)

Site SBY4 was a rectangular mound on level ground located in the north-eastern part of llama pen 4 on Sir Bani Yas island (Figure 81, no.4). It was approximately 16 x 14 m and 1-2 m high. The mound consisted of small-large grey stone rubble from coarse beach rock, brown sandy soil and small white stones (Figure 84). The stones were medium-large in size, being ca 40 x 30 x 15 cms. Outer wall footings enclosed this mound, some having traces of a light grey-white plaster, 1cm thick. Some decorated plaster fragments were also recovered. Within the mound area itself there were traces of the stone footings for some structures. A room was recognised within the south-east corner of the site. This was about 8.3 x 4.8 m externally and 5.5 x 2.5 m internally. On the north-east and south-east parts of the mound were adjoining small rectangular rooms which joined onto the courtyard on the northern side. Excavations carried out by Salvatore Garfi for ADIAS established that this was the remains of a courtyard house, very similar to SBY3. Associated pottery also suggested a 6^{th}-7^{th} century AD date for its occupation.

The faunal assemblage recovered included 34 turtle (*Chelonidae*) carapace fragments, three dugong (*Dugong dugon*) rib fragments, two sheep/goat/gazelle-sized limb bone fragments and an unidentified mammal fragment. Fish remains formed 28% of the total weight of all bones, dugong 44%, turtle 28% and terrestrial mammal, only 1%.

A total of 392 fish bone fragments were recovered, of which 27 (7%) were identified to family, genus or species level (Table 69). A total of five families were represented: flatheads (*Platycephalidae*), groupers (*Serranidae*), emperors (*Lethrinidae*), seabream (*Sparidae*) and tuna/mackerel (*Scombridae*). Fish bones occurred in five layers at the site, most of the material coming from context 25 (Appendix 5 - Tables 189-191). Flatheads, groupers and emperors were only represented by cranial elements (Table 70). Both cranial elements and vertebrae were noted for seabream, and a single posterior caudal vertebra from a tuna/mackerel was also recorded. The size of the diagnostic elements indicated that the majority of the fish were small individuals sized between 20-40cm (Table 71). The vertebrae also came from small fish (Table 72 and Figure 85).

5.2.4.3. Site SBY7, Sir Bani Yas island (SBY7)

SBY7 was a further occupation mound located in the northern part of llama pen 4 on the east side of the enclosure (Figure 81, no.7). The mound measured 24 x 20 m overall, although the structural mound was 16 x 14m with gently sloping sides, rising to a maximum height of 1.5 m. It consisted of grey stone, soil and sand with building walls being exposed to the northern and southern side. The wall on the northern side was 60 cm wide. To the north, east and west was an enclosing courtyard, the walls of which could just be seen projecting above the present day ground surface. Subsequent excavation of the site in 1996 by Liz Shepherd for ADIAS (Figures 86-87) revealed that it was also one of the typical courtyard style houses dating to the 6th-7th century AD (similar to SBY3 and SBY4). Small quantities of fish bone were retrieved during these excavations. These came from seven different layers. Context 5 was wall and ?roof collapse in Room 3, and included aeolian sand and degraded sand/mud brick. Context 7 was a deposit in which a glass vessel had been buried *in situ* sitting on a plaster floor beneath the rubble collapse in Room 1. Context 8 was a possible surface lieing in an external area to the west of the building. Context 10 represented the collapse of walls/roof into a gap in the western wall of Room 3. Context 11 also was largely formed by the collapse of rubble (roof and walls) within Room 4. Contexts 13 and 14 were the primary fills of two cupboard type features [features 58 and 59] located in the in NW corner of Room 4. These two 'cupboards' were built as a pair set against the north wall of Room 4 (the 'kitchen'), either as part of the original construction or a later addition (Figure 87).

The only non-fish remains recovered from the site were two turtle (*Chelonidae*) fragments in context 10. These were a plastron fragment and a terminal phalanx. No terrestrial mammal bones were recovered.

A total of 322 fish bone fragments were retrieved from SBY7, of which 66 (20%) were identified to family or genus level (Table 73). The bones came from seven different layers, most of the material coming from the two kitchen cupboards (Appendix 5 - Tables 192-194). Four families were represented: groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*) and seabream (*Sparidae*). Groupers and seabream were represented by both cranial elements and vertebrae, jacks by only vertebrae and emperors by only cranial elements (Table 74). The majority of the groupers, emperors and seabream came from small individuals between 20-30cm (Table 75). This was confirmed by the size of the vertebrae (Table 76 and Figure 88). A single larger vertebra was present in context 8, but this was poorly preserved and could not be identified.

5.2.4.4. Site SBY9, Sir Bani Yas island (SBY9)

Site 9 was a low flattened occupation mound approximately 220 x 160 m, reaching 1.5-2 m in height above the surrounding ground surface, located on the eastern side of Sir Bani Yas island (Figure 81, no.9). It sloped down eastwards from the higher ground to the west. The mound was a mixture of light brown sandy soil with numerous small-medium pieces of stone, mostly grey beach rock. Occasional flint nodules and tile flint were noted. Despite some signs of modern surface disturbance due to plantation work, clear concentrations of pottery were visible and a block of decorative plaster with a vine scroll in relief was recovered. Ceramics recovered from the surface all pointed towards a 6^{th}-7^{th} century AD date. Following this initial survey, archaeological excavations carried out between 1994 and 1996 subsequently established the presence of a church within a monastic complex (Figure 89). The church was about 14m in size from north to south, and 11m from east to west. It was surrounded by a walled courtyard enclosure of about 90 x 70 metres. Excavations in 1994 uncovered a block of rooms presumed to be a dormitory in the northeastern part of the courtyard (Figure 90). A magnetometer survey in 1995 confirmed that there was also a wing of buildings located in the southern half of the courtyard. A series of 12 rooms were excavated in the north-east wing, along with the central church and the main entrance gate to the monastery. This work recovered further significant quantities of 6^{th}-7^{th} century AD pottery and a number of decorated plaster panels which must have originally formed a decorative frieze around the outside of the church. Excavations carried out in the NE wing uncovered one room with an oven, which had been used as a kitchen. Abundant quantities of food debris were recovered from layers within and adjacent to this room (particularly from context 55), including large quantities of marine mollusca, fish and mammal bones. The monastery was probably founded in the late 6^{th} century and fell into disuse by the late 7^{th}/early 8^{th} century AD. The series of other buildings and courtyard houses (SBY2, SBY3, SBY4 and SBY7) excavated on the eastern side of Sir Bani Yas all had almost identical sized walls and similar plastered surfaces. This fact, along with the pottery associated with them, demonstrates that a fairly substantial early Christian community inhabited the island at this time.

A total of 1,276 g of animal bone was recovered from the excavations at SBY9. The assemblage largely consisted of fish bones which formed 48% of the total bone weight, 34% belonging to terrestrial mammals, 13% to marine mammals, 4% to reptiles and less than 1% to birds. Terrestrial mammals mostly consisted of poorly preserved post-cranial fragments from sheep/goat, a few large mammal (?cattle/equid/camel) limb bone fragments and several unidentified small mammal limb bones. Marine mammals were represented by dugong and dolphin. Both vertebrae and rib fragments were identified from dugongs. The dolphin remains consisted of a single vertebra fragment. Reptile remains included mostly carapace fragments from marine turtle, as well as limb bone fragments including two metapodaial fragments and phalanges. A few small unidentified snake bones were also noted. Crab remains occurred in 27 different contexts at SBY9. These were dominated by chelae from swimming crabs (*Portunus*), which occurred in 81% of samples. Other identifiable remains included a small xanthid crab, the hermit crab *Dardanus* and the ghost crab *Ocypode* (Peter Hogarth, pers. comm.).

A total of 8293 fish bone fragments were recovered from the excavation, of which 1651 (20%) were identified to family, genus or species level (Table 77). Twelve families were represented, including at least thirteen genera. These families included: sawfish (*Pristidae*), stingrays (*Dasyatidae*), requiem sharks (*Carcarhinidae*), sea catfish (*Ariidae*), needlefish (*Belonidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracudas (*Sphyraenidae*), parrotfish (*Scaridae*) and tuna/mackerel (*Scombridae*). Groupers present included the orangespotted grouper (*Epinephelus coioides*). The jacks/trevallies recorded included queenfish (*Scomberoides*). Pinkeared or redspot emperor (*Lethrinus lentjan*) was common amongst the emperor remains. The majority of seabream belonged to the genus *Rhabdosargus*, with smaller quantities of *Acanthopagrus* also present.

Fish bones were recovered from 60 different contexts, identifiable remains being present in half of these (Appendix 5 - Tables 195-7). Significant groups of material occurred in contexts 16, 44, 55, 127 and 176. These were all layers associated with the kitchen in the NE wing of the monastery. Important taxa represented at SBY9 were requiem sharks, emperors and seabream.

Requiem sharks and sawfish were represented entirely by vertebrae (Table 79). A stingray tail spine fragment was identified in context 116. A number of bucklers from

Chondrichthyes (?thornback rays) were recovered from contexts 55 and 133. Sea catfish was represented by both cranial elements and abdominal vertebrae. Groupers, emperors, seabream, barracudas and tuna/mackerel were all represented by both cranial elements and vertebrae. However, only vertebrae were noted in the case of needlefish, a single cleithrum fragment and vertebrae from jacks, and only pharyngeal fragments from parrotfish.

Analysis of the diagnostic elements which could be attributed to size classes revealed that the majority of the emperors and seabream were from small individuals between 20-40 cm (Table 80). Larger fish present included sea catfish (60-70cm), groupers (from 20-80cm, most being between 20-40cm), and tuna (60-70cm). Examination of the fish vertebrae size data confirms this picture that mostly small fish were caught, and that the only larger individuals caught belonged to groupers or tuna (Table 81 and Figure 91).

5.2.4.5. Sir Bani Yas - Summary

A common element of all the fish assemblages from the monastic related sites on Sir Bani Yas was the presence of predominantly small fish with taxa like requiem sharks, groupers, emperors and seabream clearly being of some importance. Relatively low numbers of larger jacks and pelagic species like tuna were observed.

5.2.5. Site LF94, Liffiyya island, Abu Dhabi emirate, UAE (LF94)

Liffiyya is a small oval shaped island located at 53°13'42"E, 24°17'44"N, situated off the NW end of the island of Merawah, opposite the village of Liffa, about 130km west of Abu Dhabi in the UAE (Figures 10 and 92). The island is 3.5km. long and 1.5km. wide. The southern and western coastlines consist of mangrove stands and tidal flats. These give way in the north and east to eroding limestone cliffs roughly two metres high, which form a series of promontories separated by little beaches. Settlement today is confined to the north-east coast, and the island has a small village on the eastern shore known as Liffiyya, with a landing beach nearby. The island landscape is dominated by sandy plains dotted with low bushes. In the central and northern parts of the island low interconnected limestone ridges, supporting little vegetation, line a sabkha inlet of considerable size which penetrates well inland from the south-west coast. Several people were still living on this island when the ADIAS team carried out its initial archaeological survey of the island in April 1992. A more detailed survey of the island (including some limited excavations) was undertaken by Jakub

Czastka, Steve Strongman and Alex Wasse for ADIAS in November 1994. This discovered a number of Early to Late Islamic sites, the majority being concentrated on the northern coast. A number of these were sampled during this fieldwork. Site 2 (Figure 92, no.2) was a stone rectangular shaped feature, dating to the Late Islamic period, located on the southern coast of Liffiya. The southern end of the feature was open, orientated NW-SE and measured 0.8 x 0.55cm. Further details of the stratigraphy of this site are provided in Appendix 6.

A number of samples were taken and processed by wet sieving to 0.5mm, and very small quantity of fish bone were recovered from layers C (S1012) and D (S1016). No terrestrial mammal or other non-fish remains were identified within these samples. A total of 69 fish bone fragments were recovered, of which 10 (14%) could be identified to family or genus level (Table 82). Layer C (S1012) only contained a few unidentifiable fish bone fragments, all the identified remains coming from layer D (S1015). A single caudal vertebra was identified as belonging to jacks/trevallies (*Carangidae*), and seabream (*Sparidae*), including the genus *Rhabdosargus*, were represented by both cranial elements and vertebrae (Table 83). The two diagnostic *Rhabdosargus* elements came from individuals sized between 20-30cm (Table 84). All the vertebrae present similarly came from small fish (Table 85).

5.2.6. Merawah island, Abu Dhabi emirate, UAE

Merawah is an island located at 53°15'00"E, 24°17'00"N, about 120 km west of Abu Dhabi in the UAE (Figure 10; Figure 92). The island is about 13 kms from east to west and 5.5 kms from north to south at its widest point. At the western end is the island of Liffiyya, separated from Merawah by a narrow channel. There are three small modern population centres on the present island: Liffa in the west, overlooking Liffiyya; Ghubba on the long southern bay of the island; and a nameless small settlement at the eastern end of the island. The remains of huts and shell mounds are present at both Ghubba and the eastern settlement, with an especially large mound at the latter. Close to Liffa is an old mosque. There are a number of important archaeological sites on Marawah (Hellyer, 1990). The most extensive sites noted are at the western end of the island to the south and south-east of Liffa.

5.2.6.1. Site MR1, Merawah island (MR1)

The most important of all the archaeological sites on Merawah is site MR1. This is located on a low, rocky coastal promontory at the south-west end of Merawah, about 2 kms south of the village of Liffa (Figure 92, no.1). Overlooking a bay, the location of the site represents the only elevated area at the western part of Merawah. The archaeological site was positioned on a limestone plateau and covered an area of about 500 x 100 m. An extensive scatter of lithics, including several hundred arrowheads, was scattered across the site and at least 54 separate structures and elements were recognised during the initial survey of the site in April 1992 (King 1998: 71). These consisted of several mounds, wall lines and rectangular structural traces, as well as possible hearths, cairns, oval depressions and stone rings. The lithics assemblage indicated that the major part of the site dated to the Late Stone Age. Three radiocarbon dates have been undertaken based on samples of ash taken from hearths at MR1. These have been dated at the Heidelberg Radiocarbon Laboratory by Dr. Bernd Kromer. Calibrations were made using the atmostpheric calibration data of Stuiver *et al* (1998) and are calculated with 2 sigma errors from the probability distributions. The results were as follows: Sample A: 6314+/-74 BP (5480-5060 cal BC), Sample B: 7036+/-30 BP (5990-5810 cal BC), and Sample C: 6446+/-56 BP (5490-5300 cal BC). Their calibration is slightly problematic, however, because the d13C-values are in the range of marine samples (Hans-Peter Uerpmann, pers. comm.). The ash sampled from the hearths may therefore have contained a significant marine component (e.g. like burnt turtle or dugong bones, or possibly mangrove wood). If the samples are calibrated against the marine calibration curve, this decreases the age of the samples by at least 400 and at most 800 years. In any case they remain the earliest dates measured up to now for any site in the United Arab Emirates and Oman peninsula.

A small number of fish bones were collected from the surface of these hearths during the 1992 initial survey of the site. These were from locus MR 1.54. Other associated material included some fragments of the gastropod shells, *Hexaplex kuesterianus* and *Planaxis,* and the bivalves, *Anadara*, *Asaphis violascens* and *Circenita callipyga*. Crab remains included two chelae from swimming crabs, *Portunus* (Peter Hogarth, pers.comm.). A total of ten fish bone fragments were retrieved, three of them being identified to family level (Table 86). Two sawfish (*Pristidae*) caudal vertebrae were noted, as well as a premaxilla from a seabream (*Sparidae*) which was from an individual 20-30cm in length (Tables 87-9).

5.2.6.2. Site MR6.1, Merawah island (MR6.1)

Sites MR6.1 and MR6.3 formed part of a group of four cairns located on the west coast of Merawah (Figure 92, no.6), ca 1km south of Liffa village, on the old coastline above the 'sabkha' or salt flats. These cairns lay immediately to the east of MR1. No surface finds were recovered from their immediate vicinity. Traces of a modern falcon perch were found on top of MR6.1. This site appeared from the surface to be a burial cairn. Subsequent excavations by Nadia Iacono and Graham Wilson for ADIAS carried out in the spring of 1999 proved it to be a pair of pre/early Islamic lime kilns (Figure 93). Associated with the kilns were some extremely abraded pre-Islamic/early Islamic potsherds (Rob Carter, pers.comm.). Confirmation of the age of the site came from two radiocarbon dates. A charcoal sample taken from layer 12, a primary fill inside the northern kiln (feature 2), produced a date of 1300 +/-50 radiocarbon years BP (OZE166), whilst layer 12 in the southern kiln was dated to 1230 +/- 50 radiocarbon years BP (OZE165). Following the calibrations of Stuiver *et al* (1998), calculated with 2 sigma errors from the probability distributions, this gives dates of 755 +/-115 AD (95.4% confidence) and 805 +/-135 AD (95.4% confidence). This means that these two kilns must have been in use sometime between the late 7th- early 10th century AD. A total of 423g of vertebrate remains were recovered from the excavation. Fish bones comprised 27% of the total weight of all bones, reptiles 61% and bird 12%. Reptile remains consisted of marine turtle (*Chelonidae*), mostly represented by carapace/plastron fragments, vertebrae, and limb bone fragments including phalanges. These were distributed throughout the site in a number of different contexts associated with both kilns. The bird remains included bones from Socotra cormorant (*Phalacrocorax nigrogularis*).

A total of 937 fish bone fragments were recovered, of which 262 (28%) were identified to family, genus or species level (Table 90). A total of nine families were represented, including at least twelve genera. The following families were recorded: stingrays (*Dasyatidae*), needlefish (*Belonidae*), cobia (*Rachycentridae*), jacks/trevallies (*Carangidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), parrotfish (*Scaridae*) and tuna/mackerel (*Scombridae*). Jacks/trevallies included the following genera: *Carangoides*, *Gnathanodon speciousus*, *Megalaspis cordyla* and *Scomberoides*. *Rhabdosargus* was the major seabream represented. Important families represented at MR6.1 were jacks/trevallies, emperors, seabream and parrotfish (Table 91).

Fish bones were recovered from 19 different contexts at the site (Appendix 5 – Tables 198-200). Most of the material came from feature 1 (layer 6) and feature 2 (layers 3 and 7). These particular contexts were a hearth and associated layers outside the kilns.

Stingrays were represented by a group of vertebrae, perhaps all from the same individual (Table 92). Only cranial elements from needlefish, cobia and grunts were noted. In the case of jacks/trevallies, emperors, seabream and parrotfish, both cranial elements and vertebrae were recorded. Tuna/mackerel was only represented by a single cleithrum fragment. The majority of the diagnostic elements which could be attributed to size classes belonged to small fish sized between 20-40 cm (Table 93). This was confirmed by a closer inspection of the size of all the vertebrae (Table 94 and Figure 94).

5.2.6.3. Site MR6.3, Merawah island (MR6.3)

Site MR6.3 is located about 20 metres to the SE of MR6.1. Excavations by Soren Blau and Nadia Iacono for ADIAS in 1998 uncovered traces of a small oval shaped sunken burial cairn. Only a few poorly preserved finds were recovered during excavation. Thermoluminescence dating of a large pottery fragment found within the cairn suggested that the site dated to the Early Islamic period (Nadia Iacono, pers. comm.). A small quantity of fish bones was recovered from a primary layer inside the burial chamber, as well as from a layer sealed by rubble towards the surface (layer 6). The only non-fish remains recovered included a small number of unidentified bird and small mammal remains which occurred in both layers. Two fragments of pearl oyster (*Pinctada* sp.) were also noted inside the chamber.

A total of 357 fish bone fragments were recovered, of which 54 (15%) could be identified to family, genus or species level (Table 95). A total of eight families were represented including at least ten genera. These included: needlefish (*Belonidae*), flatheads (*Platycephalidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*), parrotfish (*Scaridae*) and tuna/mackerel (*Scombridae*). *Carangoides*, *Gnathodon speciosus* and *Scomberoides* were recorded amongst the jacks/trevallies. *Rhabdosargus* was identified amongst the seabream. A similar range of taxa was found in both layers (Appendix 5 - Tables 201-203). Needlefish, jacks, emperors, seabream and tuna/mackerel were all represented by both cranial elements and vertebrae, whereas only a single flathead cranial element and some barracuda vertebrae were recorded (Table 96). Analysis of those diagnostic elements which could be attributed to size classes (Table 97) revealed that the majority of the remains came from small fish sized between 20-40cm, the only medium-sized individuals being needlefish (30-70cm), *Carangoides* (40-50cm) and tuna/mackerel (50-60cm). The size of the vertebrae present also suggested that mostly small fish were caught (Table 98 and Figure 95).

5.2.6.4. Site MR12.3, Merawah island (MR12.3)

Site MR12 comprised a group of at least 6-7 cairns in a line running north-south about 200 m south of site MR11, a group of seven cairns located 2 kms north-west of Ghubba (Figure 92, no.12). These were approximately 1.5 m in diameter and 40-50 cms high. They appeared to be built from flat local limestone slabs (each being roughly 50 x 30 x 5 cms) which had been piled to form low cairns. In 1999 one of these cairns, site MR12.3, was excavated by Rob Carter for ADIAS. The excavation revealed traces of a pre-Islamic burial cairn. The cairn was about 3m in its maximum diameter. A rough sub-circular chamber, ca 1m in diameter, was surrounded by flat unshaped stones. Large flat stones found in the lowest layer of the chamber may represent traces of its original corbelled roof. The chamber unfortunately was empty of human remains. Layer 8 represented the primary fill of the chamber, whilst the upper layers (1-6) consisted of sand between collapsed rubble. Very few archaeological finds were recovered. Non-fish vertebrate remains included a number of bird bones in layers 4 and 5, several bones from Socotra cormorant (*Phalacrocorax nigrogularis*) as well as from a small wader. A dugong rib fragment occurred in layer 4, and two unidentified small lizard mandibles in layers 3 and 5. Crab remains included three chelae from xanthids (Peter Hogarth, pers.comm.).

A total of 826 fish bone fragments were recovered at MR12.3, of which 89 (11%) were identified to the level of family or genus (Table 99). A total of nine families were represented, including: needlefish (*Belonidae*), flatheads (*Platycephalidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), mojarras (*Gerreidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*) and parrotfish (*Scaridae*). *Rhabdosargus* was identified amongst the seabream. Most of the fish remains came from layers 4, 5 and 8 (Appendix 5 – Tables 204-206). Seabream and emperors were ubiquitous taxa present throughout the different layers (Table 100). Needlefish, mojarras, seabream and parrotfish were only represented by cranial elements (Table 101). Most of the seabream remains consisted of teeth. Jacks/trevallies and barracuda were represented by a single caudal vertebra. Both cranial elements and vertebrae were recorded from flatheads and emperors. All the identified fish remains came from small fish sized between 10-40cm (Table 102).

The size of the vertebrae confirmed that small individuals were represented (Table 103 and Figure 96).

5.2.6.5. Site MR14, Merawah island (MR14)

Site MR14 is a shell midden located about 150m north of Merawah village, which can be found approximately two thirds northwards along the east facing coastline of the island (Figure 92, no.14). The village consists of several fishing shacks and drying racks. It overlooks several discontinuous mangrove stands and lies on an area of low lying sabkha, which according to locals is often innundated by sea-water. The village today is occupied by just one local, Darwish al-Rumaithi, who informed the ADIAS team investigating this group of particular sites (MR14-16) and that these middens were used right up until before the oil boom in the Gulf. A total of about nine raised circular midden mounds stretch northwards about 4-500 m from the village. They are located approximately 50m west of the present high water mark. Site MR14 was investigated by Jakub Czastka and Alex Wasse in December 1994 for ADIAS. The mound of site MR14 was approximately 19m in diameter, and it sloped downwards on its eastern, seaward side. The surface of the midden consisted of fine to coarse shelly sand with abundant small gastropod (*Cerithidae*), pearl oyster and limestone fragments littering its surface. A Late Islamic potsherd from a coarse tempered vessel was also recovered from these surface layers. A 1.5 x 1.5m sondage was excavated on the highest point of the midden. Further details of the stratigraphic profile are provided in Appendix 6.

The site as a whole was interpreted as representing short episodes of refuse deposition, broken up by natural aeolian components and bioturbation. Although the marked elevation of the mound visible prior to excavation seemed to hold promise as being able to provide a long sequence of midden deposits, in actual fact the raised area was largely a natural feature. This may have been partly caused by vegetation trapping some of the aeolian born deposits and encouraging dune development.

All excavated sediment was dry sieved using a 1mm mesh sieve. In addition, a number of column samples were taken for wet sieving also at 1mm. These are listed above in the description of the sequence (samples S2001, S2002 and S2004). The only non-fish remains recovered were two bird vertebrae and an unknown marine mammal bone fragment in context 2. The bird vertebrae were close in size and morphology to Socotra cormorant (*Phalacrocorax nigrogularis*).

A total of 457 fish bone fragments were recovered, of which 305 (67%) were identified to family or genus level (Table 104). A total of eleven families were represented, including at least twelve genera. The following familes were present: requiem sharks (*Carcharhinidae*), stingrays (*Dasyatidae*), eaglerays (*Myliobatidae*), needlefish (*Belonidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*), tuna/mackerel (*Scombridae*) and puffers (*Tetraodontidae*). *Carangoides* and *Scomberoides* were represented amongst the jacks/trevallies, and *Rhabdosargus* amongst the seabream. The single scombrid remain was from a Spanish mackerel (*Scomberomorus* sp.). Most of the fish remains came from context 1 spit 1 (S2001) and context 2 spit 2 (S2002) – (Appendix 5 – Tables 207-209). Needlefish were the most ubiquitous remains, followed by jacks and emperors, then groupers (Table 105). Needlefish, groupers and jacks/trevallies were all represented by both cranial elements and vertebrae; eaglerays, seabream and puffers by only cranial elements; and requiem sharks, stingrays, barracuda, and Spanish mackerel by only vertebrae (Table 106). According to those diagnostic elements which could be attributed to size classes, the needlefish came from individuals sized between 30-80cm; groupers were from 60-80cm; the *Carangoides* maxilla present was from a 80-90cm individual; emperors were between 30-70cm; the *Rhabdosargus* cranial elements all came from small 10-20cm fish; and, the puffer was from a medium-sized 50-60cm individual. Inspection of the size of the vertebrae confirmed this overall picture (Table 108 and Figure 97).

5.2.6.6. Site MR15, Merawah island (MR15)

Site MR15 is located a short distance to the north of MR14 (Figure 92, no.15). The site was also investigated by Jakub Czastka and Alex Wasse in December 1994 for ADIAS. A similar excavation method was adopted for tackling the site, a 1.5 x 1.5 m being excavated through the centre of the midden. Further details of the stratigraphic profile are provided in Appendix 6. Dry sieving of all the excavated sediment was carried out using a 1mm mesh sieve. The only non-fish vertebrate remains recovered were a bird (?Socotra cormorant) sternum fragment and a dolphin/porpoise vertebra (with fused epiphyses) in layer 6 - spit 2.

A total of 420 fish bone fragments were recovered from the excavation, of which 243 (58%) were identified to family or genus level (Table 109). Eight families were recorded, and these included: requiem sharks (*Carcharhinidae*), stingrays (*Dasyatidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*) and tuna/mackerel (*Scombridae*). *Rhabdosargus* was again noted amongst the seabream remains. The richest fish layers were context 6 – spit 2 and context 8 – spit 1 (Appendix 5 – Tables 210-212). Needlefish were again the most ubiquitous remains, followed by requiem sharks and groupers (Table 110). Needlefish, groupers, emperors and seabream were all represented by both cranial elements and vertebrae (Table 111). Requiem sharks, stingrays, jacks/ trevallies and tuna/mackerel were only represented by vertebrae. The needlefish ranged in size from 30-80cm according to the diagnostic elements (Table 112). Groupers were from medium-sized individuals between 50-70cm. Examination of the vertebra size data confirmed that whilst the majority of the remains consisted of small needlefish and jacks, some larger requiem sharks, groupers and tuna were also sometimes caught (Table 113 and Figure 98).

5.2.6.7. Site MR16, Merawah island (MR16)

Site MR16 was located near the village of Ghubba on the mid southern coast of Merawah (Figure 92, no.16). A similar excavation method was adopted as at MR14 and MR15. A 1.5 x 1.5m sondage was excavated through the deepest part of the midden. Unlike the middens at the village of Merawah, the cultural deposits here were quite substantial. Cultural deposits continued from the surface down to a depth of about a metre where natural shelly sand deposits formed the base of the sequence. Further details of the stratigraphic profile are provided in Appendix 6. This site is interesting in that it appears that the sequence illustrates the changing role of particular resources through time. Clearly at certain times large gastropods were targeted, whilst during other periods fish and different types of shellfish were eaten. The site, like MR14 and MR15, can perhaps be interpreted as representing short episodes of refuse deposition. Associated pottery also suggested a Late Islamic date for this site. All excavated sediment was again dry sieved using a 1mm mesh sieve. Non-fish vertebrate remains consisted of a small number of caprid remains. Context 13 contained fragments of a sheep/goat atlas and hyoid. Context 14 contained a rib, cervical vertebra and lumbar vertebra from sheep/goat. The same layer also included a juvenile goat skull fragment. This had traces of three cut marks to the base of its horncore bud. Crab remains included six chelae from swimming crabs, *Portunus*, in contexts 13-14 (Peter Hogarth, pers.comm.).

A total of 1059 fish bone fragments were recovered from the excavation, of which 698 (66%) could be identified to family, genus or species level (Table 114). Fourteen families were represented, including at least sixteen genera. These families were as follows: requiem sharks (*Carcharhinidae*), sawfish (*Pristidae*), eaglerays (*Myliobatidae*), sea catfish (*Ariidae*), needlefish (*Belonidae*), groupers (*Serranidae*), terapons (*Teraponidae*), jacks/trevallies (*Carangidae*), mojarras (*Gerreidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*), tuna/mackerel (*Scombridae*) and puffers (*Tetraodontidae*). Queenfish (*Scomberoides* sp.) was represented amongst the jack family. Both the king soldierbream (*Argyrops spinifer*) as well as the haffara/goldstriped seabream (*Rhabdosargus* sp.) were noted amongst the seabream. Kawakawa/little eastern tuna (*Euthynnus affinis*) and Spanish mackerel (*Scomberomorus* sp.) were recorded amongst the scombrid remains. Slightly higher concentrations of material occurred in context 12–spit 1, context 13–spits 2 and 3, and in context 14-spit1, but otherwise the fish remains were distributed fairly evenly throughout the deposits (Appendix 5 – Tables 213-215). The most ubiquitous taxa were needlefish and jacks/trevallies, followed by requiem sharks (Table 115). Spanish mackerel occurred in almost half of the samples examined but was only recorded in the upper part of the sequence, between contexts 11 and 13-spit3. The single kawakawa/little eastern tuna fragment occurred in the top of context 14 in spit 1. Needlefish, groupers, jacks, emperors, seabream and Spanish mackerel were all represented by both cranial elements and vertebrae (Table 116). Eaglerays, terapons, mojarras and kawakawa/little eastern tuna were only represented by cranial elements; and requiem sharks, sawfish, sea catfish, barracuda and puffers by just vertebrae. Those diagnostic elements which could be attributed to size classes suggested that the needlefish were sized between 30-80cm and the groupers between 30-90cm (Table 117). The terapon opercular came from a small individual between 10-20cm. The queenfish and jack remains were all from small sized individuals between 20-50cm. Mojarras were between 20-40cm. The single emperor fragment was from a 10-20cm individual. All the seabream specimens came from 10-40cm fish. The little eastern tuna dentary was from a 70-80cm individual. A single Spanish mackerel was noted which was 40-50cm, but the most of the dentaries came from 70-80cm individuals. Analysis of the vertebra size data confirmed that whilst small needlefish, jacks, emperors and seabream were present, there were also some medium to large requiem sharks, sawfish, groupers, and Spanish mackerel (Table 118 and Figure 99).

5.2.7. Site BG12, Balghelam island, Abu Dhabi emirate, UAE (BG12)

The island of Jazirat Balghelam lies at 54°32'34"E, 24°34'08"N, on the north side of the Khor Al Jile'ah, and to the south of the island of Ras Ghurab, approximately 20 kilometres north east of Abu Dhabi in the UAE (Figures 10 and 100). It is a small island, only being about 1.5km from east to west at its widest point. The highest point on Jazirat Balghelam is approximately 5 metres above sea level in the centre, tapering to 3 metres at the western end and to 4 metres at the eastern end. A sandstone ridge, now partly planted with trees, runs on a roughly east-west axis in the western half of the island. At the eastern end of the island there is a smaller, lower limestone ridge and other small limestone outcrops, some less than a metre above the surrounding land surface. The northern shore is largely open and sandy, interspersed with rocky stretches where natural stone outcrops occur in the inter-tidal zone. The southern shore is primarily low and sandy, with extensive areas of mangroves (*Avicennia marina*) which continue at the eastern end, just south of Jazirat Umm Al Barak, and along the western end. The area between the central ridge and the western mangroves is an extensive tract of land-filled 'sabkha', which is now being colonised by salt-tolerant vegetation like *Salsola* sp. (Hellyer et al. 1995).

Site BG12 was discovered in January 1996 during fieldwork carried out by Salvatore Garfi, Jakub Czastka and the author on behalf of ADIAS. Permission to visit the island was kindly granted by its owner, His Highness Sheikh Surour bin Mohammed al Nahyan, Chamberlain of the UAE Presidential Court . The site is located at the western end of the island and was formerly circa 150 m north of the southern shoreline. Within the last few years, however, landfill has taken place and the site is now located circa 600 m from the south shore. The site consists of two raised mounds circa 3 m above the high water mark. It is characterised by the presence of extensive ashy deposits and by being covered by a lot of fish and turtle bones associated with Late Islamic pottery sherds. Four stone-lined hearths are also present, although some of these have been disturbed by recent tree-planting.

Controlled surface collections of pottery and bone were carried out by the author, assisted by Jakub Czastka between 29-30 January 1997. Four zones each consisting of a 2m radius circle were selected, deliberately targeting surfaces rich in pottery and/or vertebrate remains. All surface finds were collected by hand. In order to complement this surface collected data, three test sondages were excavated to establish the stratigraphic development of the midden. All excavated sediment was dry sieved using 2mm mesh to recover finds. Further details concerning these test trenches and collection zones are provided in Appendix 6.

A total of 6,564 g of vertebrate remains were recovered. The majority of these belonged to marine turtle (*Chelonidae*), which formed 88% of the total weight (TW) of all bones. Other non-fish taxa identified included dugong (*Dugong dugon*) - 3% TW, sheep/goat or gazelle and unidentified bird - <1% TW. Fish bones comprised 8% of the total weight of all bones.

A total of 1,973 fragments (5783g) of turtle were identified, and these largely consisted of burnt carapace and plastron fragments. Other elements represented included vertebrae and limb bone fragments. One metapodial (from collection zone 4, surface of trench 3) had traces of an oblique cut mark to its proximal posterior lateral margin, suggesting that the turtles were perhaps being skinned. Turtle remains were collected in all four collection zones, although most material was concentrated in zone 4. Trenches 1 and 2 both contained turtle bones. In trench 1 this was largely concentrated in context 2, with smaller quantities present in contexts 7 and 10(S). In trench 2, turtle remains were identified in context 8(E).

Dugong was represented by a total of 13 fragments (221g). Twelve rib fragments were recovered in collection zones 2, 3 and 4, trench 1 (context 7), trench 2 (context 8) and trench 3 (context 10). A dugong limb bone fragment was also noted in Trench 1 (context 2).

The only terrestrial mammal remains recovered included a poorly preserved sheep/goat or gazelle first or second lower molar fragment (Trench 3, context 10), and several limb bone fragments from similar-sized taxa (Trench 1, context 1). Other taxa represented included four unidentified bird bone fragments were retrieved in collection zone 2 and Trench 1 (context 2). Finally, a crab chelum was also noted in Trench 2 (context 2) which may be an *Ocypode* (Peter Hogarth, pers. comm.).

A total of 900 fish bone fragments were recovered from the combination of surface collection and excavation of the test trenches, of which 137 (15%) could be identified to family or genus level (Table 119). A total of six families were represented, including: sawfish (*Pristidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*) and puffers (*Tetraodontidae*). Genera present included *Epinephelus*, *Carangoides* and *Rhabdosargus*. The majority of the remains (97%) came from sharks/rays/skates (*Chondrichthyes*), which were the most ubiquitous taxa at the site (Table 120). Most of the material was collected on the surface of collection zone 2 (Z2), at the top of the sequence in trench 3. Large quantities were also collected in Trench 3 in context 10S (Appendix 5 – Tables 216-218). A large number of vertebrae were collected (Table 121). Although many of these were too poorly preserved and fragmentary to identify beyond the level of *Chondrichthyes*, a good number could be attributed to sawfish. Groupers, emperors, seabream and puffers were only represented by cranial elements. Jacks/trevallies were represented by four scute fragments and caudal vertebrae. The grouper basioccipital fragment was from a fish sized between 70-80cm. The emperor premaxilla and puffer dentary both came from individuals sized between 30-40cm (Table 122). Analysis of the vertebra size data confirmed that most of the shark/sawfish vertebrae were from medium/large sized individuals (Table 123 and Figure 101). Some of the caudal vertebrae identified as belonging to the genus *Carangoides* were from large fish.

5.2.8. Umm al-Qaiwain UAQ1+2, Umm al-Qaiwain emirate, UAE (UAQ92-3)

Sites UAQ1 and 2 (also referred to as UAQ92-3), are located at 55°34'47"E, 25°33'36"N, towards the northern border of Umm al-Qaiwain emirate, north of the well-known archaeological site of Ed-Dur (Figures 10 and 102). In 1991 the coastline road leading northwards to Ras al-Khaimah cut through a large dune composed of midden and aeolianite deposits, and a fine bifacial arrowhead along with several flint flakes were collected from the surface of the site. In 1992 Carl Phillips and Phil Treveil (both then of the Institute of Archaeology, UCL, London) excavated two 0.50 m squares through the midden at UAQ1. This sampling exercise was authorised by the Diwan of Umm al-Qaiwain, and was carried out under the aegis of the European Expedition to ed-Dur. The fieldwork confirmed that the deposits were only a few centimetres thick and repeated survey of the midden recovered a number of Ubaid type sherds (Phillips, forthcoming). The site appeared to be very similar to a nearby site investigated by the French Archaeological Mission (Boucharlat et al. 1991), who designated it as site 69. Subsequently this site was examined by Margarethe and Hans-Peter Uerpmann who renamed it al-Madar (Uerpmann and Uerpmann 1996).

Two further 0.50 m square trenches located at either end of a 5 metre baseline were excavated on the landward side of UAQ1 on the summit of the neighbouring dune. This was named UAQ2. Subsequent excavation established that much more extensive and well-compacted deposits were preserved here (Phillips, forthcoming). An upper layer of shells was underlain by a layer of sterile sand, which lay upon a further, second layer of shells. Excavation down to ca 60cm uncovered a further layer of sterile sand overlaying another shell layer. The second trench (in square 3) identified a similar sequence of deposits but at the base of these stratified midden deposits was an ash rich deposit containing Ubaid painted sherds, mammal and fish bones, as well as a human skull. The trench was subsequently expanded so that a 0.5 m wide trench was excavated along the baseline to join up the two separate 0.5 m square trenches. This subsequently was widened by a further 0.5 m to permit excavation of a 3 x 1m area around the burials. Three articulated burials were recovered.

In 1993 the excavation area was extended to cover an area of 10 x 5 metres. The burials located in 1992 were sited approximately in the middle of the 10m axis of the trench. The stratigraphic sequence over the entire area was uniform. Up to four distinct shell horizons was interspersed with sterile sand layers. Beneath these layers lay an ash rich deposit which included a number of distinct hearths concentrated in a 4 x 2 m area where the human remains were located. The remains of a further 39 individuals were recovered by the end of the excavation. Nine individuals were recognised in their original burial position but for the most part the bones were uncovered as a mass of disarticulated and partially disarticulated human remains. This suggests that as new burials were placed at the site, earlier burials were relocated towards the margins of the central area. There was some suggestion that long bones and skulls had been placed together. Out of the minimum number of 42 individuals identified, 18 could be identified as being male adults, 14 female adults and three sub-adults. The oldest individual was about 35 years of age. Further details concerning the stratigraphic profile uncovered within these trenches is provided in Appendix 6.

A few fish bones were recovered amongst the shell layers which clearly post-date the burials but the majority of the vertebrate faunal remains were found in the underlying ash rich layers, particularly in the hearths surrounding the burials. Many of the bones are burnt and it is possible that they may represent the remains of funerary meals (Phillips forthcoming). The recovery procedure is summarised in table 124. A good proportion of most of the excavated layers was dry sieved using a 1mm mesh. The remainder of the layers were dry sieved using 4mm mesh. Non-fish remains recovered included small quantities of sheep/goat and cattle (Chris Mosseri-Marlio, pers. comm.). Numerous crab remains were also recovered from this site. These largely consisted of chelae from swimming crabs (*Portunus*), with moderate quantities of the mangrove crab (*Scylla*). Other recognisable remains included some xanthid chelae and a few fragments of another species, possibly *Calappa* (Peter Hogarth, pers. comm.).

5.2.8.1. Umm al-Qaiwain UAQ1+2 (UAQ92-3) – Fish taxa represented

A total of 6743 fish bone fragments were recovered from the Umm al Qaiwain excavations, of which 1207 (18%) were identifiable to the level of family, genus or species (Table 125). Most of the material came from the lower deposits according to the quantification of NISP, MNI and weight data (Tables 125-127). Ten families were represented: herrings/sardines/shads (*Clupeidae*), flatheads (*Platycephalidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracudas (*Sphyraenidae*) and tuna/mackerel (*Scombridae*). Only five of these families were present in the upper midden deposits: herrings/sardines/shads, snappers, grunts, emperors and seabream. *Carangoides* and *Gnathanodon speciosus* were genera present amongst the jacks/trevallies. *Rhabdosargus* was the principal seabream recorded. Scombrid remains included both Spanish mackerel (*Scomberomorus* sp.) and tuna.

The preservation of bones was mostly similar between layers; the majority of fragments being poor to medium-well preserved. Many of the bones had mineralised concretions making it particularly difficult, especially in the case of small vertebrae, to identify them. Many of the bones exhibited traces of burning to their surface: 476 out of 1859 bones in the upper midden deposits (26%), and 1817 out of 4884 bones in the lower deposits (37%). No traces of butchery such as cut marks or chops were observed to any of the Umm al-Qaiwain fish bones. A single bone specimen exhibited traces of what appeared to be carnivore gnaw marks. This was a crushed caudal vertebra fragment from an unidentified fish in layer 1020 (lower deposits) which had clear puncture marks visible to its surface.

5.2.8.2. Umm al-Qaiwain UAQ1+2 (UAQ92-3) – Elements represented

Seabream were the most ubiquitous remains in both the upper midden and lower deposits (Table 128). In the lower deposits emperors and barracuda were also common. Most of the fish bones recovered within the upper midden deposits came from layers 3C and 4B intermingled with the shell deposits (Appendix 5 - Tables 219-221). These largely consisted of seabream vertebrae and cranial elements (including loose teeth), as well as a few emperor otoliths (Table 129).

Amongst the lower deposits, the majority of the fish bones occurred in layers 1012 (the thick 30cm thick shell and sand deposit) and layer 4C (the sandy ashy layer below 1012) – (Appendix 5 – Tables 222-224). Moderate quantities occurred in two of the hearths (layers 1014 and 1023), as well as in layer 7, only small quantities of fish bones being present in the other layers. The material in these layers also largely consisted of seabream (*Sparidae*) cranial elements and vertebrae, as well as emperor (*Lethrinidae*) otoliths (Table 130). Herrings/sardines/shads (*Clupeidae*) were represented by a small number of vertebrae in both the upper and lower deposits. An articular in layer 7 in the lower deposits was identified as belonging to an indian flathead (*Platycephalus indicus*). A single abdominal vertebra belonging to grouper was identified in layer 1023 of the lower deposits. Jacks/trevallies were represented by both cranial elements and vertebrae. Snappers (*Lutjanidae*) occurred in small quantities in the upper midden deposits. Layer 1010 contained what appeared to be a pair of maxillae from the same individual, judging from their similar size. In addition, layer 6B contained an otolith identified as being from a dory/blackspot snapper (*Lutjanus* cf. *fulviflamma*). The lower deposits contained further bone specimens attributable to snapper. These consisted of a range of cranial elements. A grunt (*Haemulidae*) otolith was identified from layer 3A in the upper midden deposits. Comparison of the morphology of this specimen with modern comparative material indicated that it belonged to the genus *Pomadasys*, and possibly to the spotted grunt, *Pomadasys commersonnii*. The majority of the otoliths identified as belonging to emperors belonged to the pinkear (or redspot) emperor, *Lethrinus lentjan*. Four otoliths from pinkear emperors were recorded in layer 4B from the upper midden deposits. In the lower deposits, a total of 61 otoliths were noted from this species. These occurred in the 30cm thick shell and sand deposit (layers 6D and 1012), in the sandy ashy layer below it (layer 4C and 1043), and amongst five of the discrete hearths (layers 1014, 1017, 1021, 1023 and 1025). The emperor otoliths from Umm al-Qaiwain will be discussed in further detail in the following chapter in the section on seasonality (Chapter 7.5 –7.10). The lower deposits also contained moderate quantities of cranial elements from emperors (*Lethrinus* sp.) but relatively few vertebrae. Human burial 1 in the lower deposits contained a single emperor hyomandibular fragment.

Those sparids identifiable to genus or species level all belonged to the goldstriped or haffara seabream, *Rhabdosargus* sp. Considerable quantities of cranial elements were identified, including many dentaries and premaxillae as well as loose teeth. Some of the loose teeth were the characteristic oval-shaped single posterior teeth found in the premaxilla and dentary of the genus *Rhabdosargus*. Many of the vertebrae which could only be identified to the level of family probably also belonged to this genus judging from their relative size. Particular concentrations of such material occurred in layers 3C and 4B in the upper midden deposits, and in layers 1012, 4C, 1014 and 7 in the lower deposits. A single *Rhabdosargus* otolith was present in both the upper midden and lower deposits (layers 4B and 1006 respectively). Human burials 1, 2 and 3 in the lower deposits all contained small quantities of seabream, burial 1 including two dentaries, two premaxillae and a maxilla from at least two different individuals. Barracudas only occurred in the lower deposits, and were represented by vertebrae and two otoliths. Tuna/mackerel only occurred in the lower deposits. A single caudal vertebra was identified to the genus *Scomberomorus* from layer 1020. Three caudal vertebrae and an ultimate caudal vertebra in layer 7 were identified as being from some sort of tuna (*Thunninae*, indet.). These probably belonged to either the kawakawa, *Euthynnus affinis*, or to the yellowfin, bigeye or longtail tuna, *Thunnus* sp. Human burial 1 contained three tuna specimens, a dentary from a very large individual (see discussion below), plus a caudal and ultimate caudal vertebra.

5.2.8.3. Umm al-Qaiwain UAQ1+2 (UAQ92-3) – Size of fish

Those diagnostic elements which could be attributed to particular size classes all came from small fish which were mostly sized between 10-30cm (Table 131). The only medium-sized taxon present was *Gnathanodon speciosus*, three cranial elements coming from an individual sized about 40-50cm. The vertebra size data confirmed that predominantly small fish were present (Table 132 and Figure 103). The herring/sardine/shad (*Clupeidae*) vertebrae present in both the upper and lower deposits were very small in size (Table 15). It is salutary to note that if sieving had not been carried out using a 1mm mesh then the presence of these fish would undoubtedly have been missed. A small number of vertebrae came from small to medium-sized jacks and emperors. All of the barracuda vertebrae present in the lower deposits were quite small. This may be because they are from juvenile or sub-adult individuals, or it may be that the bones are from one of the smaller species occurring in the region. The size of the vertebrae suggested individuals of less than 60cm length compared with modern comparative material. One of the two barracuda otoliths was complete enough to measure. The specimen from layer 1043 had a maximum breadth vs. height of 8.8 x 4.4 mm. This otolith looked morphologically closest to a specimen of yellowtail barracuda, *S.flavicauda*, although it could only be compared against comparative specimens of *S. jello*, *S. putnamiae* and *S. qenie*. The Spanish mackerel and tuna vertebrae present all came from individuals less than a metre in length based on comparisons with reference examples.

5.2.8.4. Umm al-Qaiwain UAQ1+2 (UAQ92-3) – Summary

Seabream, particularly the genus *Rhabdosargus*, as well as the redspot emperor, *Lethrinus lentjan*, formed the main part of the fish bones recovered from the site. A total of 65 otoliths were identified from the latter species. These will be discussed in further detail in Chapter 7.5 – 7.10. It is interesting to note that human burial 1 contained three tuna bones. One of these was a dentary from an extremely large individual of more than 120cm. On the basis of its size, it is more likely that this belongs to *Thunnus* rather than *Euthynnus*. This was the largest fish found at the entire site and it may be significant that it was deliberately selected for inclusion with the burial. It is worth noting that the two tuna vertebrae also present in the same burial were also the largest specimens out of all the tuna vertebrae represented at the site, having a maximum width of 14mm.

5.2.9. Ed-Dur North, Umm al-Qaiwain emirate, UAE (EDN)

The site of Ed-Dur is located in the emirate of Umm al-Qaiwain in the UAE (Figures 10 and 104). Between 1987 until the early 1990s the European Archaeological Expedition to ed-Dur, comprising a Belgian, British, Danish and French team undertook excavations there (Boucharlat et al. 1988, 1989; Haerinck and Stevens 1989; Lecomte et al. 1989; Potts 1989). The site of Ed-Dur North is a circular enclosure at the north end of the well known archaeological site of Ed-Dur, located near to a radio mast (Figure 104). It was investigated by Carl Phillips in 1988. A number of small trenches were excavated through various parts of the circular enclosure ditch. The area of the enclosure did not appear to have occupation that extended on post-Iron Age into the Ed-Dur period. All of the excavated contexts provided abundant pottery which could be dated to the early Iron age. This material was predominantly Iron II, with no Iron III material being present (Peter Magee and Carl Phillips, pers. comm.). The walls were made of pisé on a foundation of small stones. Two bronze fish hooks were recovered but no net weights were discovered. Small quantities of fish bones were retrieved during the excavation. Faunal remains were retrieved by a combination of hand recovery and dry sieving using a 4mm mesh sieve. No finer sieving was carried out to check for the presence of very small fish remains. Smaller more fragile bones may of course have been missed during the excavation, leading to the under-representation of smaller fish within the assemblage. Other non-fish remains recovered from the site included a small number of sheep/goat bones (Chris Mosseri-Marlio, pers.comm.). Two contexts (layer 2100 and 2119) also contained chelae from swimming crabs (*Portunus*) – (Peter Hogarth, pers. comm.)

A total of 245 fish bone fragments were examined, of which 69 (28%) could be identified to the level of family, genus or species (Table 133). Eight families were represented: sawfish (*Pristidae*), groupers (*Serranidae*), jacks (*Carangidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracudas (*Sphyraenidae*), parrotfish (*Scaridae*) and tuna/mackerel (*Scombridae*). Genera recorded included: *Epinephelus*, *Carangoides*, *Gnathanodon*, *Lethrinus*, *Rhabdosargus*, *Sphyraena* and *Scarus*.

The bones were fairly evenly distributed throughout the different excavated contexts (Appendix 5 – Tables 225-227). No particular taxon dominated the assemblage (Table 134). The preservation of the bones was also very similar between all layers, the majority of fragments being medium-well preserved. Small quantities of burnt bones only occurred in three layers (2119, 2122 and 2123). No butchery traces were observed on any of the bones. A single bone showed possible traces of tooth marks to its surface. This was a very large shark/ray/skate (*Chondrichthyes*) caudal vertebra; the diameter of the breadth of its centrum was 36mm. The tooth marks were in the form of punctures typical of the damage caused by the canines of a medium-sized carnivore. It seems more likely that these were made by a dog rather than a fox judging from the size of the puncture marks. If carnivores have been active on the site then this may have affected the representation of fragile smaller fish remains (Jones 1984, 1986).

Groupers, jacks/trevallies, emperors, seabream and barracuda were all represented by boith cranial elements and vertebrae. A single upper pharyngeal fragment was identified to parrotfish. Sawfish, shark/ray/skate and tuna/mackerel were only represented by vertebrae (Table 135).

The limited number of diagnostic elements which could be attributed to particular size classes suggested the following, that groupers ranged between 40-100cm, the golden trevally (*Gnathanodon speciosus*) between 40-70cm, emperors between 20-60cm, seabream between 10-40cm, barracuda between 50-80cm and parrotfish between 40-50cm (Table 136). The vertebra size data confirmed that small/medium sized sawfish, large groupers, small jacks, emperors and seabream, and medium-sized barracuda and tuna were present (Table 137 and Figure 105).

5.2.10. Kush, Ras al-Khaimah emirate, UAE (KU)

The site of Kush is located at 56°01'54"E, 25°49'05"N on the western edge of the Shimal plain area of Ras al-Khaimah in the UAE (Figures 10 and 106). It presently lies amidst densely planted date-palm groves and small rural settlements. Although it is now about two and a half kilometres from the modern coast, it formerly lay within 300 metres of the edge of an old lagoon which was still navigable when described by Lorimer (1908-15). This lagoon has however now silted up to become a *sabkha* flat. Shell middens can be found along the edges of the *sabkha* flat from which a few sherds of 12-13th century pottery have been found indicating that the lagoon existed during the later period of Kush's occupation and was exploited for shell-fish at that time.

Kush was first discovered by Beatrice de Cardi during her 1977 survey of Ras al-Khaimah who described an "extensive area of high mounding [...] covered with late Islamic pottery" in the Shimal area of Ras al-Khaimah (de Cardi 1985: 179, site 40f). In 1994 Derek Kennet excavated a small sondage which confirmed that the mound contained an occupation sequence dating from the Sasanian period to the 13-14th century AD (Kennet 1997, forthcoming). Subsequently five seasons of excavation took place at the site between 1995-99 directed by Derek Kennet from the University of Durham (UK), with permission from the Director of the Antiquities and Museums of Ras al-Khaimah, Sheikh Sultan bin Saqr al-Qasimi. This work confirmed that Kush is the only substantial settlement in the northern Oman Peninsula with an occupation sequence spanning the pre to early Islamic period. It also represents one of the very few sites on the Arabian side of the Gulf to contain convincing evidence of 11th to 14th century occupation (Kennet, pers. comm.). Four trenches were excavated at the site between 1994-99 (Figure 107). Further details concerning the stratigraphy and phasing of the site are provided in Appendix 6. For the purposes of this analysis these various levels can be summarised into the following five chronological periods:

- Sasanian (Period 1: Phases 15-12)
- Early Islamic (Period 2: Phases 11-9)
- Abbasid (Period 3: Phase 8)
- 12-13th century (Period 4: Phases 4-2)
- 16-17th century (Period 5: Phases 1)

A Sasanian period settlement was represented by massive mud-brick fortifications with associated settlement traces. The fortress wall stood to a height of over 2 metres and was built on the lower edge of the mound which formed over about three centuries of earlier occupation (Kennet 1997, forthcoming). After a relatively short period of occupation the fortress was abandoned and seems to remain that way for a couple of centuries. During this period the massive mud-brick wall began to erode and large quantities of silt and gravel washed in and began to fill the interior of the fort, in some places being up to a metre thick. It was not until the 8-9th century AD when the site was resettled. Initially the settlement probably only consisted of date-palm-frond type houses which soon developed into more substantial mud-brick architecture. Although the site almost certainly underwent periods of decline and growth by the end of the 13th century it seems to have been finally abandoned for good. Evidence for settlement at the site did not reappear until the 16-17th century AD when some traces of palm-frond-type houses were identified.

The most complete stratigraphic sequence was obtained from trench A. It was also from this trench which the abundant vertebrate remains (including fish bones) were recovered. The location of trench A cut through the highest part of the tell through the edge of the western mound and revealed the most complete occupation sequence (Figure 108). The trench measured 10 metres N/S and was 20 metres E/W. All excavated earth from the trench was dry sieved using 3mm mesh. As the post-excavation programme for this site is still underway, and will not be completed until the end of 2001, it was only possible to analyse material which had been already stratigraphically dated by pottery analysis. The present analysis is based on the study of about 60% of the contexts excavated from phases 12-9, covering the Sasanian, Early Islamic and Abbasid phases of occupation at the site.

Mammalian remains identified from the site were dominated by ovicaprid remains, with more bones being identified to goat rather than sheep (Beech and Pipe 1997; Beech in prep.). Smaller quantities of cattle were also noted. Pig occurred predominantly in the

Sasanian and some of the early Islamic layers. Other taxa represented included dog, cat, equid, ?oryx, marine turtle, unknown marine mammal and bird. Crab remains included mostly chelae from swimming crabs (*Portunus*), with smaller quantities of mangrove crabs (*Scylla*) and *Ocypode*, and some xanthid remains (Peter Hogarth, pers. comm.).

5.2.10.1. Kush – Fish taxa represented

A total of 7140 fish bone fragments were recovered amongst the aforementioned deposits, of which 865 (12%) were identified to family, genus or species level (Table 138). Thirteen families were represented, including at least 21 genera. The following families were noted: requiem sharks (*Carcharhinidae*), milkfish (*Chanidae*), flatheads (*Platycephalidae*), sea catfish (*Ariidae*), needlefish (*Belonidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), mojarras (*Gerreidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), tuna/mackerel (*Scombridae*) and triggerfish (*Balistidae*). The following genera were represented amongst the jacks/trevallies: *Carangoides*, *Elagatis*, *Gnathanodon*, *Megalaspis* and *Scomberoides*. *Acanthopagrus*, *Argyrops* and *Rhabdosargus* were all noted amongst the seabream. Scombrids included tuna, both *Euthynnus* and *Thunnus*, as well as Spanish mackerel, *Scomberomorus*.

Most of the studied material came from the early Islamic period, only small quantities of bones being recorded from the Sasanian and Abbasid periods (Tables 139-141; Appendix 5 – Tables 228-230). This variation between phases is largely an effect of the progress of the stratigraphic phasing of the site, and the information provided to the author. Once the full dating of all the deposits has been completed it will be possible to include more samples from the other phases (Derek Kennet, pers. comm.).

Only seabream have been so far determined within Sasanian levels. These include *Acanthopagrus*, *Argyrops spinifer* and *Rhabdosargus*, of which the latter was the commonest type. Abbasid levels included sea catfish, jacks/trevallies and triggerfish. In the Early Islamic levels, seabream was the most ubiquitous family represented, followed by tuna/mackerel and jacks/trevallies (Table 142).

5.2.10.2. Kush – Elements represented

The Sasanian levels contained mostly cranial elements from seabream, particularly from the genus *Rhabdosargus* (Table 143). Bones were poorly preserved and this may account for the sparse remains.

In the Early Islamic levels, groupers, jacks/trevallies, emperors, seabream and tuna/mackerel were all represented by both cranial elements and vertebrae (Table 144). Only cranial elements from flatheads, mojarras, and grunts were noted. Requiem sharks, milkfish and Spanish mackerel were only represented by vertebrae.

Abbasid levels included both cranial elements and vertebrae from sea catfish and jacks/trevallies (Table 145). Needlefish were only represented by vertebrae, and triggerfish by its distinctive specialised basipterygium.

5.2.10.3. Kush – Size of fish

All the diagnostic seabream elements in the Sasanian levels came from small fish sized between 10-40 cm (Table 146). During the Early Islamic period, notable quantities of small sized fish also occurred although more medium to large fish were present. Flatheads ranged between 30-40cm and groupers between 30-70cm. Amongst the jacks/trevallies, *Carangoides* ranged between 20-80cm (mostly 30-50 cm), the golden trevally (*Gnathanodon speciosus*) between 30-60cm, and queenfish (*Scomberoides*) between 50-60cm. Mojarras were between 20-30cm and grunts between 30-60cm. Diagnostic elements from emperors came from small fish sized between 10-50cm (mostly 20-40cm). Seabream were also small, ranging from 10-40 cm (mostly 20-30cm). Tuna were the largest fish caught in the Early Islamic levels. A number of kawakawa/little eastern tuna (*Euthynnus affinis*) diagnostic elements came from individuals sized between 70-90 cm. The other tuna represented, *Thunnus* sp., had diagnostic elements from individuals sized between 60-90 cm. Abbasid levels contained medium to large sized jacks ranging between 20-80cm.

The vertebra size data confirmed this general picture (Table 147-8 and Figure 109), including the presence of medium to large sized fish. During the Early Islamic period, requiem sharks (*Carcharhinidae*), milkfish (*Chanidae*), groupers (*Serranidae*), *Carangoides*, rainbow runner (*Elagatis bipinnulata*), golden trevally (*Gnathanodon speciosus*), torpedo scad (*Megalaspis cordyla*), queenfish (*Scomberoides* sp.), Spanish mackerel (*Scomberomorus* sp.) and tuna were all represented by medium or large sized vertebrae. Smaller fish were represented by vertebrae from jacks/trevallies, emperors and seabream. In the Abbasid levels, most of the sea catfish and needlefish vertebrae came from small-medium sized individuals. The size range of jack/trevally vertebrae suggested that whilst mostly smaller individuals were present, some medium to large individuals also occurred.

5.2.10.4. Kush – Summary

Most of the studied material came from the early Islamic period, only small quantities of bones being recorded from the Sasanian and Abbasid periods. In the Early Islamic levels, seabream (*Sparidae*) was the most ubiquitous family represented, followed by tuna/mackerel (*Scombridae*) and jacks/trevallies (*Carangidae*). Jacks included *Carangoides*, rainbow runner (*Elagatis bipinnulata*), golden trevally (*Gnathanodon speciosus*), torpedo scad (*Megalaspis cordyla*), and queenfish (*Scomberoides* sp.). Scombrids present included both tuna species, *Euthynnus affinis* and *Thunnus*, as well as Spanish mackerel, *Scomberomorus*. Other taxa represented included milkfish (*Chanos chanos*).

5.2.11. Site UNAR2, Shimal, Ras al-Khaimah emirate, UAE (UNAR2)

The Umm an-Nar period tomb called UNAR2, is located in the Shimal region of Ras al-Khaimah emirate in the UAE (Figures 10 and 106). The tomb was discovered late in 1996 during the construction of a road in the Shimal area. Preliminary excavations of the site took place in the spring of 1997, followed by further work in early 1998 which was completed in 1999. Excavations were carried out by Derek Kennet, Joe Elders and Christian Velde for the Department of Antiquities and Museums of Ras al-Khaimah, financially supported by Serco/IAL Ltd (Velde 1998). This work revealed a circular tomb measuring 14.3 m in diameter with 12 separate internal chambers forming three separate units. The tomb represents one of the largest communal tombs so far discovered in the Arabian Peninsula. Preliminary assessment of the ceramics and beads suggests the site is typical of the late Umm an-Nar period, i.e. dating to about 2300-2100 BC. All the excavated sediment from the fills of each of the internal chambers was dry sieved using 3mm mesh rocking sieves. Further information concerning the archaeology of the tomb and details concerning its human remains are provided in Appendix 6.

Two nearly complete crania were recovered from Chamber C and two articulated adult individuals, a male in Chamber D and a female associated with an articulated dog burial in Chamber G (Blau 1998; Blau and Beech 1999). Semi-articulations were also recorded in Chambers D and K. Most of the human skeletal remains showed some degree of burning (91%), many (70%) being predominantly burnt white suggesting that they had been exposed to high temperatures. Most of the human remains could only be assigned to a general adult category, although there were remains of foetal, infant, children and adolescents also present within each chamber. Apart from the aforementioned dog skeleton, small quantities of mammal, fish and reptile bones, as well as crustacea remains, were recovered within several chambers inside the tomb (Blau and Beech 1999). Mammalian remains included several sheep/goat fragments. A number of carapace fragments from marine turtle (*Chelonidae*) were also noted. The crab remains included two chelae from swimming crabs, *Portunus*, and one from a mangrove crab, *Scylla* (Peter Hogarth, pers. comm.).

A total of five fish bones were recovered from stratified contexts within the tomb, of which four were identifiable to the level of genus (Table 149). Context 1019.5 contained an unidentifiable vertebra fragment. A requiem shark vertebra was found within chamber B (context 1060.2). The maximum breadth of this vertebra was 8mm. Tuna (*Thunnus* sp.) vertebrae were identified from two separate chambers within the tomb. Chamber G (context 1042.2) included an abdominal vertebra, and chamber J (contexts 1054.2 and 1064.3) contained two caudal vertebrae. Based on comparisons with modern comparative material, these tuna vertebrae probably came from individuals sized between ca. 60-80cm.

5.2.12. Shimal SH602, Ras al-Khaimah emirate, UAE (SH602)

The tomb called SH602 is located at UTM grid ref. 40 R 402540/2856390 in the Shimal region of Ras al-Khaimah emirate in the UAE (Figures 10 and 106). This is about 400 metres west of the Shimal settlement (Vogt and Franke-Vogt 1987; von den Diresch 1994). During an archaeological survey in advance of road construction being carried out by the Ras al-Khaimah Baladiyya, two collective stone-built tombs were discovered. Limited excavation and cleaning established that one of the tombs (SH602) was directly threatened by the road construction; the other, SH601 was planned, photographed and backfilled with sieved earth for possible future investigation (Kennet, pers. comm.). Between the 12th January and the 6th February 1997 a rescue excavation was carried out at SH602 by Derek Kennet, then resident archaeologist at the National Museum of Ras al-Khaimah. The tomb is located at the westerly extent of the gently sloping gravel fan which spreads from the foot of the mountains and levels out on the finer silt of the date-palm groves less than 100 metres to the west. The site appears to be one of the most western tombs connected with the Shimal Wadi-Suq cemetery. Further details concerning the excavation and stratigraphy are provided in Appendix 6.

Finds recovered from the excavation included pottery, softstone vessel fragments, human bones and a small quantity of mammal and fish bones. A small number of sheep/goat (*Ovis/Capra*) bones were recovered, of which one horncore fragment belonged to a goat. Four turtle (*Chelonidae*) limb bone fragments and a crab chelum (*Portunus* sp.) were also present (context 16.1). A jird (*Meriones* sp.) mandible almost certainly represents a modern intrusion into the deposits judging from its fresh appearance, suggesting that rodent activity may have disturbed some of the deposits. A total of 11 fish bone fragments with a total weight of 34g were recovered from the excavations at Shimal 602 (Table 150). The fragments were generally poorly preserved, the surfaces of the bones being moderately eroded with some evidence of root damage. Contexts 3.1 and 6.1 both contained single examples of large shark caudal vertebra, approximately 3cm in diameter. Context 14.1 contained a dentary from a haffara/goldlined seabream (*Rhabdosargus* sp.). This was from a small individual sized between 20-25cm. A number of small fragments from hyperostotic neurocrania were also noted in several contexts (3.1, 6.1, and 16.1). These may belong to jacks/trevallies (*Carangidae*).

5.2.13. Rafaq 2, Ras al-Khaimah emirate, UAE (RFQ2)

The site of Rafaq 2 is situated in the Wadi al-Qawr, east of Huwaylat, at the southern limit of the emirate of Ras al-Khaimah in the UAE (Figure 10). It is located approximately 25 kilometres from the eastern Gulf of Oman (Batinah) coast. The Wadi al-Qawr is located towards the northern end of the Hajar mountains, and acts as an east-west corridor between the Madam plain at its western end with the northern Batinah coast at its eastern end. An initial archaeological survey of the region was carried out by Beatrice de Cardi and Brian Doe in 1982 (de Cardi and Doe 1983; de Cardi 1984). This demonstrated the presence of a number of probable third millennium BC burial cairns, as well as a variety of other tombs and settlements dating from the mid to late first millennium BC. Subsequent work by Phillips proved that the area had been more continuously occupied than had previously been thought, probably from as early as 3000 BC through to 300 BC (Phillips 1997: 205).

At Naslah, located at the eastern end of the Wadi al-Qawr, two tombs dating to the late Wadi Suq/early Iron age were recorded by de Cardi and Phillips (de Cardi 1984, site 3; Phillips 1997, Naslah 1). On the opposite side of the Wadi the partial remains of an early Iron age settlement was discovered (de Cardi 1984, site 6; designated as Naslah 3 by Phillips 1997). Just west of this site further traces of an early Iron age settlement, designated as Rafaq 1, were discovered by Phillips. Excavation at the site uncovered similar rectangular structures to those at Naslah 3 although with the addition of a number of circular (?animal) enclosures situated adjacent to the main structures (Phillips 1997: 213). Directly opposite Rafaq 1, on the north side of the wadi is another Iron age site (de Cardi 1984: site 4; designated as Rafaq 2 by Phillips 1997). Rafaq 2 is sited on top of a prominent hill with a commanding view of the wadi below. Subsequent excavation of this site uncovered the plan of a multi-roomed building with courtyard areas and a flight of stairs leading from the wadi up towards a building at the northern end of the site (Phillips 1997: 215). This excavation recovered typical early Iron age pottery like large cordoned storage vessels, as well as a large ovoid storage jar with white slip and a distinct purple-brown fabric with large yellow inclusions, probably imported from Bahrain (Phillips 1997: 215, fig. 10). Some of the upper layers excavated were mixed contexts (ie. they contained possible contamination from later Islamic/recent occupation). Material from these layers was excluded from the present analysis.

The faunal assemblage at Rafaq 2 was recovered by a combination of hand recovery and some dry sieving using a 4mm mesh (Carl Phillips, pers. comm.). Moderate quantities of mammalian and fish vertebrate remains were recovered during the excavation of these deposits. The mammalian remains included sheep/goat and small quantities of cattle (Chris Mosseri-Marlio, pers.comm.). Crab remains occurred in 21 samples at the site (Peter Hogarth, pers. comm.). These largely consisted of chelae from the mangrove crab, *Scylla*, which occurred in 13 of the 21 samples. Two samples contained chelae from swimming crabs, *Portunus*.

A total of 164 fish bone fragments were examined, of which 120 (73%) could be identified to the level of family, genus or species (Table 151). As relatively few unidentified bones were noted it seems likely that much of the Rafaq 2 assemblage was probably collected by hand. This means that smaller fish species may be very well under-represented within the assemblage. Eight families were represented: requiem sharks (*Carcharhinidae*), sawfish (*Pristidae*), groupers (*Serranidae*), jacks (*Carangidae*), snappers (*Lutjanidae*), emperors (*Lethrinidae*), seabream (*Sparidae*) and tuna/mackerel (*Scombridae*). Genera represented included *Carcharhinus, Epinephelus, Scomberoides, Lethrinus, Euthynnus* and *Thunnus.*

The preservation of the bones was very similar between all layers, the majority of fragments being medium-well preserved. Only 6% of the bones were poorly preserved. The only bone to show clear traces of burning to its surface was a single tuna/mackerel (*Scombridae*) vertebra in layer 34.28. No butchery traces, teeth marks or signs of digestion were observed to the surface of any of the bones.

Bones were distributed fairly evenly between the different excavated layers at the site (Appendix 5 – Table 231). The most ubiquitous taxa present appeared to be tuna/mackerel (*Scombridae*). They occurred in the majority of excavated layers containing fish bones. Six specimens could be identified more precisely. Four of these belonged to kawakawa/little eastern tuna (*Euthynnus affinis*). Three vertebrae were recovered in layer 5.5, articulating 2nd, 3rd and 4th abdominal vertebrae from the same individual. In addition, a quadrate was retrieved in layer 42.3. Two scombrid caudal peduncles in layers 6.18 and 50.7 were identified to the genus *Thunnus* sp. on the basis of their general morphology. Most of the scombrid remains could only be identified to the level of family. However, these all seemed to belong to *Thunninae* rather than to mackerels. They consisted entirely of vertebrae, the majority of which were caudal (40%) and penultimate/posterior caudal (53%) vertebrae (Table 152). Other taxa identified included requiem sharks (*Carcharhinidae*), sawfish (*Pristidae*), groupers (*Serranidae*), jacks/trevallies (*Carangidae*), emperors (*Lethrinidae*), and seabream (*Sparidae*), which were all only represented by vertebrae. Snappers (*Lutjanidae*) were represented by two maxillae.

Those few diagnostic elements which could be attributed to size classes suggested that the two snappers present belonged to 30-40 and 50-60cm individuals (Table 153). The quadrate in layer 42.3 came from a kawakawa/little eastern tuna which was between 50-60cm. Analysis of the vertebra size data suggests that mostly medium to large-sized fish were present (Table 154 and Figure 110). However, this may be partly an affect of the recovery procedure utilised on the excavation. Medium to large-sized requiem sharks, sawfish, grouper, jacks/trevallies and tuna vertebrae occurred, as well as some smaller seabream vertebrae.

5.2.14. Kalba 4, Sharjah emirate, UAE (KAL)

Kalba 4 is located at the southern end of the Shimaliya, just north of the Batinah coast on the eastern coast of the UAE (Figure 10). It is situated in the heart of the present day agricultural area, about 8km north of the Khutum Melaha outcrop (which marks the modern border between the UAE and Oman) and is approximately 1.5 km west of the present day sea coast (Figure 111). The site was first discovered in 1993 by Carl Phillips during his survey of the extensive cairn fields around the town of Kalba. This initial work demonstrated the presence of a large non-funerary site which was clearly of some importance judging from the size of its structures and the extraordinary quantities of 3rd-1st millennium BC pottery and softstone vessel fragments collected from its surface. The site rose to about 2.5 m above the surrounding ground level. Excavations began in 1993, when permission was granted to excavate the southern part of the site, and have continued each season up to the present time. The size and depth of deposits at the site became obvious after a deep sounding was made down through the top of the mound. This revealed at least 5.6m depth of deposits, whilst a further trench in front of the mound, in square 43, also reached about 5m below the present day ground level, being ca 7m below the top of the mound. For the purposes of this study only the material from the first three season's excavations (1993-95) is analysed as this is the only material which has so far been dated and evaluated by analysis of the stratigraphic and pottery data (Carter 1997). Seven major phases were identified, two of which were divided into two sub-phases (Table 155 and Figures 112-3). Further more detailed information concerning the stratigraphy of the site is provided in Appendix 6.

The site of Kalba 4 as a whole has a quite remarkable sequence of almost uninterrupted occupation history from the 3rd to 1st millennium BC. Continuously inhabited settlements exist throughout the Wadi Suq period and into the Iron age period, although the population does seem to have been less dynamic during the late Bronze age. No subsequent traces of occupation were identified at the site, although modern bulldozing and landscaping may have destroyed some of these traces. The retrieval of fish bones during the first few seasons at Kalba (1993-5) was carried out predominantly by dry sieving using 4mm mesh. A small amount of the bones also being hand recovered. This generally ensured the recovery of bone fragments greater than 4mm in size but did not allow for the unbiased recovery of very small fish bones. Non-fish remains recovered at Kalba include predominantly ovicaprid remains and small quantities of cattle (Chris Mosseri-Marlio, pers.comm.). Numerous crab remains were also retrieved during the excavation. These are largely dominated by chelae from mangrove crabs (*Scylla*), with smaller quantities of swimming crabs (*Portunus*). A partial chela frament from a fiddler crab *Uca*, probably *Uca lactea*, was also noted (Peter Hogarth, pers.comm.).

5.2.14.1. Kalba 4 – Fish taxa represented

A total of 617 fish bone fragments were examined, of which 239 (39%) could be identified to the level of family, genus or species (Table 156). Nine families were represented: requiem sharks (*Carcharhinidae*), sawfish (*Pristidae*), groupers (*Serranidae*), jacks (*Carangidae*), grunts (*Haemulidae*), emperors (*Lethrinidae*), seabream (*Sparidae*), barracuda (*Sphyraenidae*) and tuna/mackerel (*Scombridae*). Genera represented amongst the jacks/trevallies included *Carangoides*, *Elagatis* and *Gnathanodon*; seabreams included *Argyrops* and *Rhabdosargus*; and scombrids included tuna, *Euthynnus* and *Thunnus*, as well as mackerel, *Scomberomorus*.

Preservation of the bones was very similar between all layers, the majority of fragments being of medium condition. Some of the bone fragments were poorly preserved (about 10%), the surfaces being heavily concreted with salts. Many of these specimens were from level 16.002 in Phase 2B. Very few bones showed clear traces of burning (only 3%). No traces of carnivore gnawing or damage were observed to the surfaces of the bones, although a single fragment had traces of what appeared to be gnawing marks made by some sort of rodent. This was a hyperostotic neurocranium fragment from phase 2 (level 32.028), which belonged to a king soldierbream (*Argyrops spinifer*). This specimen had clear tooth marks visible along its posterior margin. Only one bone showed traces of butchery marks. In phase 6-7 (level 36.006), a basipterygium fragment had traces of two oblique cutmarks. Unfortunately it was not possible to identify this to species, although it appeared closest morphologically to the specialised basipterygium found in triggerfish (*Balistidae*).

Most of the fish bone assemblage was recovered from the Iron age levels at the site (Iron I-II, Phases 4B-7), with few bones present in earlier levels (Appendix 5 - Table 232). Jacks and trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) were the most ubiquitous fish remains found throughout the site, occurring in 50% of all studied samples (Table 160). The commonest genus of carangid identified was *Carangoides*.

5.2.14.2. Kalba 4 – Elements represented

Requiem sharks (*Carcharhinidae*) were represented by a small number of caudal vertebrae in phases 3, 4, 6 and 7 (Table 161). A single sawfish (*Pristidae*) vertebra was identified in phase 3 (level 22.020). Groupers (*Serranidae*) occurred in phases 3, 4 and 6/7. Both cranial elements and vertebra were represented. At least three species of jack were present. Many of these belonged to the genus *Carangoides*, which occurred in 37% of all samples with identifiable fish remains. This genus was represented by both cranial elements and vertebrae. Most of the cranial elements were hyperostotic neurocrania fragments. These looked quite close morphologically to a similar hyperostotic specimen from a longnose trevally, *Carangoides chrysophrys*, in my reference collection (Appendix 3). Similar examples from other jack species have been published by von den Driesch (1994, fig.10a). A single caudal vertebra was identified in phase 1 (level 13.024), as belonging to a rainbow runner, *Elagatis bipinnulata*. Two hyomandibulars were identified in phases 6/7 (level 43.021) to golden trevally, *Gnathanodon speciosus*. Bones which could only be identified to the level of family (*Carangidae*, indet.) comprised cranial elements as well as vertebrae. Four caudal vertebrae were identified from grunts (*Haemulidae*). These were from phase 4B (level 27.007) and 6/7 (levels 33.051 and 36.006). Emperors (*Lethrinidae*) were present in phases 3, 4B/6 and 6/7. Both cranial elements and vertebrae were present. Seabream (*Sparidae*) occurred in phases 1, 1/2, 2, 3, 4B, 4B/6, 5 and 6/7. King soldierbream (*Argyrops spinifer*) was represented by a number of distinctive hyperostotic neurocranial fragments, and other cranial elements. One of these specimens had been gnawed by a rodent, and another had a shiny polished surface which suggested that it may have been handled or used for some unknown purpose. Several cranial elements were identified to haffara/goldlined seabream (*Rhabdosargus* sp.). Vertebrae were only identified to the level of family (*Sparidae*, indet.). A single abdominal vertebra was identified as barracuda (*Sphyraenidae*: *Sphyraena* sp.). This was from phase 6/7 (level 36.006). Tuna/mackerel (*Scombridae*) occurred in phases 1, 2, 2/3, 3, 4B, 4B/6, 5, 6 and 6/7. Kawakawa/little eastern tuna (*Euthynnus affinis*) was represented by two dentary fragments in phases 4B (level 27.007) and 5 (level 42.013). Spanish mackerel (*Scomberomorus* sp.) was identified from several abdominal and caudal vertebrae in phases 2, 4B, 4B/6 and 6. A caudal peduncle fragment was identified to the tuna genus, *Thunnus*. Those bones which would only be identified to the level of family (*Scombridae*, indet.) largely consisted of fragmentary vertebrae and a few poorly preserved cranial elements. These probably belonged to tuna (*Euthynnus* or *Thunnus*) judging from their relative size and appearance.

5.2.14.3. Kalba 4 – Size of fish

Those diagnostic elements which could be attributed to particular size classes suggested that predominantly medium to large fish were present (Table 162). Most specimens came from fish sized between 50-70 cm in length (58%). Although the sample size is rather poor between the different site phases, there did not appear to be any substantial changes in the size of fish through time. Groupers (*Serranidae*) were all medium-sized individuals between 40-70 cm. A number of these belonged to the genus *Epinephelus*. Amongst the jacks (*Carangidae*), those specimens identified to the genus *Carangoides* were all from fish sized between 50-90 cm. Similar sized 50-70cm individuals were also recorded belonging to golden trevally (*Gnathanodon speciosus*). Material which could only be identified to the level of jack family (*Carangidae*, indet.) was also largely from medium-sized fish, although some smaller individuals between 20-40 cm were also present in phase 6/7. The few examples identified as emperors (*Lethrinidae*: *Lethrinus* sp.) were all from adult sized individuals between 40-70 cm. Amongst the seabream (*Sparidae*), examples of the king soldierbream (*Argyrops spinifer*) were all from individuals sized between 40-70 cm. A small number of specimens were identified as being from haffara/goldlined seabream (*Rhabdosargus* sp.) in phase 4B and 4B/6. These were all from fish sized between 20-30cm. Material which could only be identified to the level of seabream family (*Sparidae*, indet.) was from individuals sized between 30-60 cm. These may come from larger members of the seabream family like *Argyrops spinifer* and species within the genus *Acanthopagrus*. Amongst the tuna/mackerel (*Scombridae*), the two diagnostic elements identified to kawakawa/little eastern tuna (*Euthynnus affinis*) were from individuals sized 60-70 and 80-90 cm. The single diagnostic element identified from the genus *Thunnus* was from a 70-80 cm fish.

Analysis of the relative size of the vertebrae from Kalba also indicated the predominance of mostly medium to large fish (Table 163 and Figure 114). Vertebrae from requiem sharks (*Carcharhinus* sp.) and sawfish (*Pristidae*) were all quite large in size. All the grouper (*Serranidae*) vertebrae were from medium sized fish, matching with the diagnostic cranial elements. The jack/trevally (*Carangidae*) vertebrae mostly came from medium to large sized individuals, although a few smaller examples were also present in phase 4B, 4B/6, 6 and 6/7. The single caudal vertebra identified to rainbow runner (*Elagatis bipinnulata*) was from a large fish. Emperor (*Lethrinidae*) vertebrae matched with the diagnostic cranial elements and all came from medium-sized individuals. The grunt (*Haemulidae*) vertebrae present were also similarly from medium-sized fish. Seabream (*Sparidae*) vertebrae were from both small and medium-sized fish. Those vertebrae identified as being from spanish mackerel (*Scomberomorus* sp.) all came from large fish. Most of the vertebrae identified to the level of tuna/mackerel family (*Scombridae*, indet.) were from large fish. Many of these probably belonged to *Euthynnus* or *Thunnus*. A number of smaller vertebrae present may belong to smaller species present within the scombrids.

5.2.14.4. Kalba 4 – Summary

Most of the Kalba fish remains were recovered from the Iron age levels at the site (Iron I-II, Phases 4B-7). Jacks/trevallies (*Carangidae*) and tuna/mackerel (*Scombridae*) were the most ubiquitous fish remains found throughout the site, occurring in 50% of all studied samples. The commonest genus of carangid identified was *Carangoides*. Both tuna species, *Euthynnus affinis* and *Thunnus* sp. were present at the site. Umm an-Nar levels included a caudal vertebra from a large-sized rainbow runner (*Elagatis bipinnulata*). Mostly medium to large sized fish were recorded.

5.2.15. Summary

This lengthy chapter has outlined the results of the zooarchaeological analysis of 23 sites located in the Arabian Gulf and Gulf of Oman. It provides the primary data for the analysis which continues in the following chapters. This dataset more than doubles the total number of studied fish bone assemblages in this region. Overall this study confirms the general established subsistence pattern, whereby coastal communities relied extensively on generalized marine exploitation along with ovicaprid pastoralism (Chapter 2.24). However, the results highlight that there are clearly some variations in the occurrence of particular fish taxa, as well as in the size of fish caught between different areas of the Gulf and Gulf of Oman. Whether these difference are simply due to preservation, recovery bias, identification problems, or other important factors will be discussed in the following chapter.

As there do not appear to be any obvious chronological trends visible amongst these 23 assemblages, the sites will therefore be discussed in the following chapter by regions, using the various countries located in the Gulf as proxy indicators for environmental or ecological areas. This also allows for a direct comparison with the modern fisheries data within each of these areas.

CHAPTER 6.

THE ENVIRONMENT AND ECOLOGY OF FISHERIES IN THE ARABIAN GULF AND GULF OF OMAN: A ZOOARCHAEOLOGICAL VS. MODERN PERSPECTIVE

The goal of this chapter is to examine both zooarchaeological and modern fisheries data to evaluate different spatial areas within the study region.

- How does differential preservation affect our interpretation of the zooarchaeoogical assemblages?
- What effect do butchery and processing activities have on the formation of archaeological fish bone assemblages?
- Do recovery biases strongly affect the results of this regional study?
- What problems are there with the identification of the archaeological fish remains?
- What problems are there using modern fisheries data?
- Can we use various ecological modelling techniques to discern meaningful patterns within the study region?

This chapter initially discusses some of the problems involved in modelling fish exploitation in the region. Some of the likely biases are discussed which may have influenced the composition of fish bone assemblages, including differential preservation (section 6.1), butchery and processing activities (section 6.2), recovery bias (section 6.3), identification problems (section 6.4.) and problems interpreting modern fisheries data (section 6.5). An attempt is then made to reconstruct the ancient fishing preferences, examining each area in turn (section 6.6 – 6.6.8). This evaluation is carried out on a spatial rather than chronological basis because, as it will subsequently be demonstrated, there appear to be strong reasons for taking such an approach. The variability in crab assemblages within the Arabian Gulf and Gulf of Oman is first discussed (section 6.7), followed by an assessment of the variability in fish bone assemblages within the same region (section 6.8). Various approaches are used to model the fish data, including percentage sample presence (section 6.8.1), sample size and ecological diversity indices (section 6.8.2.), cluster analysis (section 6.8.3.) and Renkonen's percentage similarity (section 6.8.4).

6.1. Differential preservation

An inherent problem in using the bone and body part distribution of fish to infer differences between archaeological sites is the question of bone survival. Many factors can affect this, and one of these can be the density and morphology of particular elements. However, other less controllable factors may also dramatically affect the survival of fish bones including destruction by carnivores and rodents (Jones 1983, 1986), scavenging (Walters 1984), burning and cooking (Richter 1986, Nicholson 1996), weathering (Bullock and Jones 1987), and trampling (Jones 1987). Subsequently, human factors, such as the impact of particular butchery or processing techniques, may also affect which fish and particular elements enter the archaeological record (Belcher 1991, 1994, 1998; Zohar and Cooke 1997).

Preservation of bone remains on many sites in SE Arabia is generally poor. Fortunately some of the shell middens on the coast have better preservation due to the large amounts of calcium and phosphate deposited with the molluscan debris (Uerpmann 1989: 163). However, in many cases the fish remains recovered from coastal sites still show marked signs of weathering and cracking. This is largely caused by salt damage. In some cases, the particular chemistry of the site deposits may affect the bones so a hard calcium accretion accrues around the specimen, making it almost impossible to identify. Sites within the interior of SE Arabia have provided some faunal remains but these are generally less well preserved with few bones being identifiable.

Although low numbers of parts of the appendicular skeleton like cleithra and posttemporals may be an effect of some form of butchery or processing activities (section 6.2.), more prosaic explanations may simply account for their relative absence. Both elements are not so easily identified as other cranial elements and may not preserve so well in archaeological deposits. The morphology of certain taxa and elements also means that it is more likely that they survive and are subsequently encountered by the analyst. In the case of calcified vertebrae from *Chondrichthyes*, their drum-like shape means that when trampled into the surface a greater percentage of them may survive than compared with other more fragile vertebrae from certain *Osteichthyes* (personal observation). Hyperostotic neurocranial and other skeletal elements are quite common amongst certain fishes within tropical regions (Meunier and Desse 1994; von den Driesch 1994; Smith-Vaniz et al. 1995). Hyperostosis causes swelling of the bone thereby increasing its density and the likelihood of its survival, e.g. most of the neurocranial fragments identified in the present study belong to hyperostotic skulls from jacks/trevallies (*Carangidae*) and the king soldierbream (*Argyrops spinifer*). Other species like grunts (*Pomadasys* spp.) may develop quite spectacular hyperostotic neurocrania where the whole skull becomes like a hardened small shoe (von den Driesch 1994; Meunier and Desse 1994; Bädstober 2000: 13, fig.6). Some taxa may also have a particular distinctive morphology which makes them more readily identifiable. Eaglerays (*Myliobatidae*) have distinctive pavement teeth. Sea catfish (*Ariidae*) neurocranial fragments have a characteristic granular texture. Otoliths from sea catfish are quite robust and bulbous in shape making their survival more likely, and giving them greater visibility as compared with smaller thin elongate or oval otoliths, particularly where recovery procedure have not used fine mesh sieving. Seabream (*Sparidae*), and to a lesser extent emperors (*Lethrinidae*), have strong molariform teeth which are set into quite hard compact dentaries and premaxillae. Such remains may even survive on quite poorly preserved sites, albeit only in the form of loose teeth. Parrotfish (*Scaridae*) have very recognisable sturdy upper and lower pharyngeal elements which may survive well. In the case of tuna, the posterior caudal vertebrae are particularly robust and may survive preferentially to the anterior vertebrae.

In the spring of 1995 the author buried a number of whole fresh fish at a depth of ca.75cm below the surface in a sand pit which formed part of a garden area on the island of Sir Bani Yas. This was not set up as an experiment but simply because it was the teams's final day on the island and there was not sufficient time to process all the fish which had been collected. These fish were modern specimens collected from Sir Bani Yas and Dalma island, and included sea catfish (*Arius* sp.), orangespotted grouper (*Epinephelus coioides*), and spangled emperor (*Lethrinus nebulosus*). The fish were all buried enclosed in fine nylon mesh bags so that no elements would be lost. All specimens were buried at the same depth in a line with 2m between each fish. The burial conditions are probably quite similar to those occurring on coastal sites in the region. The sediment matrix consisted of a fine shelly sand. As the burial location was situated in a private garden belonging to the President of the UAE there was little chance that it would be disturbed. The island is a private reserve and visitors may only go there with special permits. No dogs or cats are allowed on the island. Two years later all these skeletons were retrieved. All anatomical elements were recovered, including the scales in the case of the grouper and emperor.

Whilst the grouper and emperors bones were quite hard and well preserved, all the catfish bones were quite greasy, spongy and soft in texture. Albeit that in no way was this a rigorously controlled experiment, it demonstrates that the bones of certain taxa may not survive so well as others.

A summary of the preservation and fragmentation data at the 23 archaeological sites presented in this study are detailed in Appendix 7. This illustrates the point that most material was highly fragmented. There were few traces of destruction by carnivores or rodents and signs of butchery marks, but the degree of fragmentation of the material may have limited such observations. Moderate quantities of burnt bone were present at a few sites, and this seems to have enhanced the preservation of otoliths at site SBY9 on Sir Bani Yas island, and at Umm Al-Qaiwain. Weathering and salt cracking, as well as trampling, undoubtedly have influenced the composition of the fish bone assemblages.

6.2. Butchery and processing activities

Two recent studies carried out in sub-tropical and tropical regions, where similar fish faunas are encountered to those from the Arabian Gulf and Gulf of Oman, demonstrate that cultural factors may also play an important role in the selection and survival of particular fish species and elements.

Belcher (1991, 1994, 1998) has carried out an ethnoarchaeological study of South Asian fisherfolk. This work involved direct observation of traditional butchering techniques used by the fish markets of the riverine Punjab province and the marine coast of Sindh province in Pakistan. His study demonstrated that there was a clear difference between the way fishes were handled and subsequently butchered, which largely depended on whether they were to be dried and salted or sold fresh. Dried fish were gutted and the entrails discarded, the body and head being split longitudinally. Fish smaller than 25cm were dried whole. In the case of fresh fish, the butchery methods utilised varied according to the class and size of fish. Heads, entrails and the vertebral column were usually discarded at the market in the case of *Chondrichthyes*, just the tails and fins being prepared for foreign export, although some shark meat was cut into strips and sold. Butchery of *Osteichthyes* depended on the size and type of fish.

Zohar and Cooke (1997) have described similar traditional methods used to dehydrate fish by salting and sun/wind drying in Panama. They also demonstrated that a significant factor was the size of the fish, rather than its morphology, which determined which of the two butchery methods were used. The first method (used for the butchery of silver grunts, *Haemulopsis*) involved splitting the fish with a longitudinal cut along its mid-ventral line, removing all the entrails and gills, then making a few oblique cuts on the sides of the fish to facilitate salt penetration. Finally, a cut was often made descending obliquely from the dorsal fin out over the caudal peduncle. The second method utilised was to make a longitudinal cut dorsally, starting at the base of the caudal fin, extending to the anterior of the skull. This method was used for the Pacific crevalle jack (*Caranx caninus*), as well as for sea catfish (*Ariidae*). In the case of the latter species, the first dorsal spine and predorsal plate were removed before the cut was made. The fish was then opened from the dorsal region, exposed entrails being discarded, before the fish was turned over and additional transverse cuts were made on the flesh (Zohar and Cooke 1997: 60-61). A common feature of both butchery methods was the loss of branchial elements. The first method did not cause damage or loss of any neurocranial bones, but othe cranial bones like the cleithrum, coracoid and basypterygia were often damaged. Fish butchered using the second method did damage both neurocranial and cranial elements. In the case of both species, the most frequently damaged bones were the ethmoid, vomer, frontal, exoccipital, parasphenoid and basioccipital. Other less frequently damaged or lost cranial elements affected included the cleithrum, coracoid, premaxilla, quadrate. metapterygoid, epihyal, preopercular, interopercular and urohyal (Zohar and Cooke 1997: 64). Zohar and Cooke's final conclusion was that small fish that weighed less than 400g and measured less than 325 mm (standard length), suffered less damage than the bones of large fish. Both butchering methods caused considerable loss of branchial arch bones. In the case of large fish, several neurocranial and other cranial elements were damaged, but for small fish, the bones of the neurocranium were not damaged, although some appendicular bones were particularly damaged.

However, an inherent problem in using the bone and body part distribution of fish to infer a difference between sites (e.g. consumer vs. production sites) is the question of bone survival. The density and morphology of particular elements will affect their chance of preservation. As Belcher points out (1998: 404), one of the urgent future challenges for ichthyo-archaeologists working in tropical and semi-tropical environments is to develop density measurements for a wide variety of fish families. This will then allow for a better understanding of the density dependent aspects of differential preservation. Many zooarchaeologists working in such regions do not necessarily record all the elements identified by Zohar and Cooke (1997) as being characteristic of particular butchery processes (e.g. Leach 1986). This means that such information may be missed. The diversity of fish species in tropical regions means that, by neccessity, most workers only identify a very restricted number of skeletal elements. In the present study, some of the characteristic elements discussed by Zohar and Cooke (1997) were recorded, namely the vomer, general neurocrania fragments, premaxilla, quadrate and cleithrum. Although generally low numbers of some of these elements like cleithra may be an affect of some form of butchery or processing activities, more prosaic explanations may simply account for many of these differences.

A further problem is that small fragile bones from some species may simply not survive. This may be due to a number of environmental factors, but cultural reasons may also play an important role. The fact that many of these small fish may be used as fodder for livestock, as well as fertiliser, has already been mentioned earlier (Chapter 4.3). Rather alarmingly for ichthyo-zooarchaeologists working in this region, several of the traditional recipes in the UAE and Oman involve pulverising whole dried examples of such fish in a mortar, the resulting fish crumbs/powder are then kept in a jar for later use. Such a product is sprinkled over traditional bread ("khamir" or "chebab") in the UAE (personal observation at a traditional bread making demonstration at Dubai Heritage village). Dried anchovies or sardines are also ground together with toasted fennel seeds to make a garnish called "sahnah" for rice in the UAE, whilst in Oman, red pepper and garlic are pounded with the anchovies to make a similar condiment (Iddison 1998: 7). Such recipes may have been used in the past. Grinding stones are certainly known from a number of archaeological sites and it may be possible to undertake residue trace analysis of some of these to ascertain the likelihood of such practices going back into antiquity.

6.3. Recovery bias

The standard sieve mesh used on most archaeological sites now excavated within the Arabian Gulf and SE Arabia is 4mm. Unless finer mesh sieving (using 1mm) is carried out, this means that collected samples will be biased against the retrieval of some smaller anatomical elements from medium sized fish like teeth and otoliths. Recovery will also be biased against the retrieval of small fishes which have small fragile elements. Taxa like sardines (*Clupeidae*) and anchovies (*Engraulidae*) will almost certainly be missed, as well as other taxa like silversides (*Atherinidae*), smaller members of the flathead family (*Platycephalidae*), and a number of families within the order, Perciformes. These include fishes such as terapons (*Teraponidae*), cardinal fishes (*Apogonidae*), breams (*Nemipteridae*), mojarras (*Gerreidae*), ponyfish (*Leiognathidae*), goatfish (*Mullidae*), and smaller members of the mullet family (*Mugilidae*).

6.4. Identification problems

Once the material has been recovered we are still faced with the problem of identification. As Uerpmann (1989), and more recently Desse (1995), have both pointed out, one of the major problems remaining is not only having adequate osteological reference collections (Chapter 5.1.1), but even identifying the modern specimens collected in the region. Although taxonomic problems have to a certain extent been sorted out for some families, there is still considerable confusion over others. In the case of families like the sardines, herrings and shad (*Clupeidae*) and mullets (*Mugilidae*), there still appears to be much taxonomic confusion in the modern fisheries literature. In the past some zooarchaeologists have confidently identified bones to particular species, however, in many cases this is because of ignorance over the modern taxonomy, or undue optimism. Examples include making the assumption that all sea catfish bones belong to the giant sea catfish (*Arius thalassinus*), whereas at least three other species within this genus are also known in the Gulf. The identification of the seabream genus *Acanthopagrus* to species level also seems dubious (e.g. *A.berda* and *A.bifasciatus* - Badstöber 2000: 32; *A.bifasciatus* – Desse and Desse 2000). The present author cannot see any clear morphological criteria allowing *A.bifasciatus* and *A.latus* to be separated within the comparative collection constructed for this study. The assumption that only the goldstriped seabream (*Rhabdosargus sarba*) exists in the region is common, whereas it is now clear that the haffara seabream (*Rhabdosargus haffara*) is also present. Identifying particular species of tuna within the same genus, *Thunnus*, also seems problematic, although this has been carried out by some authors (e.g. *T.albacares*, *T.obesus* and *T.tonggol* - Desse and Desse 2000). However, this may simply be due to the lack of extensive comparative material from other tuna species in the author's collection. In this present study, the author has tended to be a "lumper" rather than a "splitter". This partly reflects the range and diversity of species present in the osteological reference collection but also the fact that in many cases it is not realistic to identify many of the fishes below the level of family or genus. Skeletal differences in the morphology of species within the same genus (and even sometimes family) can be negligible.

A further difficulty connected with identifying the archaeological remains is the fact that small fish tend to be only represented by vertebrae. These are extremely difficult to identify. In this study some effort was made to identify these but many could only be classified as small Perciformes or unknown fish. The size of all reasonably complete vertebrae was however recorded, so that at least if they were not identified some idea could still be provided of their relative size. The diversity of small taxa may therefore be a bit larger than some of the archaeological fauna lists suggest. At some sites the smallest vertebrae were poorly preserved or salt encrusted that little else could be done other than to measure them and note their presence.

6.5. Modern fisheries data - problems

The modern fisheries data has a number of inherent problems. Most of the available information are based on commercial landings at harbours and fish markets throughout the region. This information is usually only available at the level of family. Fisheries officers working in the regional record centres may also amalgamate some of these statistics (Chapter 3.7.1). Such statistics also mask "bycatch", i.e. fish thrown away or disposed of at sea. These usually consist of species which are considered at the present day to be of low economic value like sea catfish (*Ariidae*). In the case of sharks and rays, the fins may be cut off, the rest of the body being thrown back into the sea. This means that such taxa may be under-represented in the total landing weights. Few underwater surveys have been carried out in the region and even these may have certain biases towards less cryptic species.

6.6. Reconstructing ancient fishing preferences

Bearing in mind some of the above caveats, the contrasting picture provided by the zooarchaeological assemblages and modern fisheries data will now be discussed. This will be carried out on a country by country basis as these broadly act as proxy indicators for regional environmental or ecological conditions. In the case of the lower Gulf, the UAE is divided into three separate regions, the Abu Dhabi coastline, the northern Emirates Gulf coast, and the east (Gulf of Oman) coast. In the following main section (cf. 6.7), the overall variability of these assemblages will be evaluated using a combination of techniques, including percentage occurrence, ecological diversity indices (Shannon-Wiener and Simpson diversity index), cluster analysis and Renkonen's percentage similarity index.

6.6.1. Kuwait

The fish taxa represented at the 5th millennium BC site H3 largely inhabit shallow inshore waters. Many of the requiem sharks (*Carcharhinidae*) are found in inshore waters, including the common whitecheek shark (*Carcharhinus dussumieri*). Eaglerays are generally caught in open waters but even these may congregate in shallow waters (personal observation). Many of the taxa represented at H3 favour shallow sandy or muddy bottoms (e.g. sawfish, sea catfish, flatheads, emperors and the seabream species, *Argyrops spinifer*), some even being able to withstand estuaries and brackish waters (e.g. sea catfish and seabream species like *Acanthopagrus berda* and *A.bifasciatus*). Others favoured reefs or turbid areas adjacent to coral reefs and rocky banks on silty sand or seagrass bottoms (e.g. groupers). All of them could have been caught close to the coast. There is little evidence to suggest that much fishing was carried out in deeper offshore waters. The few large groupers (*Epinephelus* sp.) and jacks (*Carangoides* sp.) observed could represent fish caught in deeper waters off the edge of reefs, but even these fish can also enter shallow waters. As all excavated layers were sieved to 4mm it seems likely that the small numbers of larger fish does reflect the fact that relatively few big fish, including pelagics like tuna, were caught. The 1mm sieved sample from context 55 at H3 also demonstrated the importance of very small fish to the inhabitats of the site. Such fish may have been caught in the shallow waters of Kuwait Bay, adjacent to the site. Elements from the appendicular skeleton like the post-temporal and cleithra were only observed in low numbers from the larger fish (groupers and jacks), and large numbers of sea catfish otoliths were discovered but relatively few other anatomical elements from this species. This may be an effect of the differential preservation affecting this species discussed earlier.

The only two other archaeological fish assemblages already published from Kuwait are those from the island of Failaka (Chapter 4.1.2 and 4.1.3). In the early 2nd millennium BC Dilmun period levels at site F6 the recovery of the assemblage was primarily by hand (Desse and Desse-Berset 1990). This may partly explain the emphasis on larger fish like groupers and jacks/trevallies. More fragile elements of some of these fish were also poorly represented, e.g. only a single grouper cleithrum fragment was recorded at F6, most of the remains consisting of vertebrae (Desse and Desse-Berset 1990: 68, fig.21). The presence of large groupers at F6 as well as the occurrence of angelfish (*Pomacanthidae*) may suggest a greater emphasis on fishing over reefs. However, the fact that fish like sea catfish, seabream and emperors were also present demonstrates that some similar sand and mud bottom habitats were exploited. Other taxa represented at F6 suggest that predominantly shallow coastal species were exploited. No material from *Chondrichthyes* were identified at F6. Whether this is a question of poor preservation of these remains or inadequate recovery procedures remains uncertain. The requiem shark vertebrae at H3 mostly were <8mm in diameter, so poor recovery at F6 may explain their apparent absence. The later Hellenistic levels at site F5 at Failaka were also dominated by groupers, followed by jacks/trevallies then other taxa (Desse and Desse-Berset 1990). Fishing appears to have been predominantly carried out in shallow coastal waters. Recovery biases again may account for the lack of some species including *Chondrichthyes*. The presence of parrotfish (*Scaridae*) suggests again that some fishing may have been carried out on or adjacent to reefs. Requiem sharks are seldom observed on Kuwaiti reefs and are more common off the reef edge or away from the reef (Downing 1987: 12). This may also explain their absence from Failaka if fishing largely concentrated on the reef areas. As sea catfish and seabream were also present, clearly sand and mud bottom habitats were also being exploited. A distinctive characteristic of site F5 was the occurrence of croakers (*Sciaenidae*), mostly belonging to the genus *Argyrosomus*. These fish form small schools over muddy bottoms in nearshore areas to depths of 60m (Carpenter et al. 1997: 188).

A notable feature of both sites at Failaka was the complete absence of any bones from tuna/mackerel (*Scombridae*), whereas at H3 a dentary from a medium-sized (40-50 cm) tuna, as well as a number of vertebrae were recovered. This is perhaps surprising given the fact that other smaller taxa are represented in the Failaka assemblages. The presence of some reef-associated taxa like angelfish and parrotfish may simply reflect the fact that the reefs are much more developed off and around Failaka Island than in the waters of Kuwait Bay, and that fishing tended to concentrate in these areas.

The range of taxa recorded in the zooarchaeological assemblages matches well with modern fisheries data from Kuwait (Chapter 3.2). Hussain and Abdullah (1977) noted that groupers, seabreams and croakers were all important commercial species exploited in the region. The size range of the groupers identified at H3 and the sites on Failaka matches their description of the size range seen in their study of modern orange spotted groupers. One contradiction was the study by Gubanov and Schlieb (1980) which demonstrated that sea catfish (*Ariidae*) were numerous in the area but that they were largely ignored in the modern fisheries. Other scarcely used species reported by them included *Carangoides* and *Decapterus*. All these taxa are represented at H3, and the presence of sea catfish was also noted at both the sites on Failaka. This indicates that species which are considered to have low economic value today clearly were not necessarily treated so in the past. The orangespotted jack (*Carangoides bajad*) is actually one of the commonest species of jack recorded on Kuwaiti reefs according to Downing (1987). Gubanov and Schlieb (1980) also noted the occurrence of the spotted Spanish mackerel (*Scomberomorus guttatus*) and narrowbarred Spanish mackerel (*S.commerson*) but did not mention any tuna species. This may be largely due to the fact that their study was based on a trawl survey, which may also explain the preponderance of pomfrets and croakers. Groupers were also noted as being the most important fish caught in Kuwaiti waters during 1984 according to Morgan (1985). The abundance of seabream in the NW waters of the Gulf, as well as the fact that croakers (*Sciaenidae*) were only recorded in these waters within the Gulf, was also commented upon by Koronuma and Abe (1986). A number of studies carried out on the ageing of fish in Kuwaiti waters indicate that many fish species migrate from offshore to inshore for breeding or feeding in the spring-summer period, when catch rates are higher (Hussain and Abdullah 1977; Mathews and Samuel 1983; Abu-Hakima 1987). Kuwait Bay has been identified as an important nursery ground, and many juveniles appear in coastal waters during the summer season most fish species spawn in Kuwaiti waters between the late spring to early autumn (Houde et al. 1986). The twobar seabream (*Acanthopagrus bifasciatus*) as well as the onespot seabream (*Diplodus kotschyi*) are common in the late spring and summer months as they come to the reefs for breeding (Downing 1987: 16). Tuna and mackerel were only occasionally recorded on or near Kuwaiti reefs, although large schools of the Indian mackerel (*Rastrelliger kanagurta*) were seen off one reef close to the surface. A recent study by Ye et al. (2000) has demonstrated that croakers form an important component of the bycatch made by shrimp trawling, and also noted like the earlier study by Gubanov and Schlieb (1980) sea catfish represented 30% of the discarded bycatch.

6.6.2. Saudi Arabia

The fish bones from the early 5th millennium BC site of Abu Khamis on the Saudi Arabian Gulf coast have not yet been studied (Chapter 4.1.1.). A preliminary scan of the assemblage suggested that sharks/rays/skates, jacks and tuna were all common, with groupers and seabream also being present at the site (personal observation). Even though precise details of the recovery of this assemblage are not clear, it is interesting that bones from tuna appear to be common if compared with the Kuwaiti sites at the northern end of the Gulf.

The study of the early 5th millennium BC material from Dosariyah represents the first detailed analysis of fish remains from a coastal archaeological site in this region. Whilst the remains were collected almost thirty years ago by Masry (1974, 1997), it is fortunate that all this material has been curated in the National Museum of Natural History at the Smithsonian Institution in Washington D.C. It is assumed that all the bones stored there represent the bulk of the material collected during the excavation, however, this cannot be certain. The recovery methods utilised to retrieve this material are unfortunately not clearly defined in the publication by Masry (1974, 1997).

The surface material was probably hand collected, judging from the fact that all the vertebrae were >12mm in diameter. However, some sieving was probably used to recover the faunal assemblages in the excavated trenches, as vertebrae as small as 2mm are found in trench 1, and 5-6 mm in both trenches 5 and 7. The surface material may be contaminated by later periods, although the archaeological material collected from consisted entirely of Ubaid pottery and stone implements with no overlay of pottery from any later date on the site (Masry 1997: 78-80). If one accepts that some of the surface collected bones are contemporary with the associated pottery, then it is interesting that tuna remains are far more common here than at the aforementioned sites in Kuwait, evern though the sample sizes are similar. As some of the bones represented are posterior caudal vertebrae this may partly be simply an effect of preservation (cf. 6.1.). The similar range of taxa, including requiem sharks, sawfish, and seabream, suggests that, similar to the Kuwaiti sites, fishing may have partly concentrated in shallow sandy bottom habitats. Although the presence of some quite large jacks and groupers reflects the fact that hand recovery was utilised, it may indicate that some fishing may have been carried out in deeper waters.

Most of the shark and ray remains also originated from the upper layers of trench 1 at Dosariyah, corroborating their presence in the general surface layers. Large quantities of seabream cranial elements were noted throughout the excavated layers, with very few vertebrae. Similar deposits from broadly contemporary sites have been identified in Bahrain and Qatar (Chapter 6.4.4 – 6.4.5.). Such remains may result from the differential preservation of these elements, although it has been suggested that sparid heads may have been removed as some form of processing (Desse 1988). The range of taxa represented in trench 1 suggested that a variety of inshore coastal habitats were exploited including sand and mud bottoms (for sea catfish, emperors and seabream), as well as reef areas (for large groupers and parrotfish). A few tuna vertebrae were noted but these were again mostly posterior caudal vertebrae. Trench 5 contained a similar range of taxa to trench 1, including seabream cranial elements, although the remains of tuna were more common. A number of tuna vertebrae were recovered from a floor, as well as from layer 3 sealed below it. They were mostly abdominal and anterior caudal vertebrae. These floor deposits also included two cranial elements from kawakawa/little eastern tuna (*Euthynnus affinis*) from individuals sized between 80-90cm. The fact that both cranial and vertebral elements are present suggests that whole fish in some cases may have been brought to the site. In trench 7, only small quantities of tuna were noted, as in the case of trench 1. Seabream cranial elements again dominated with comparatively few vertebrae being noted. Some of the groupers and jacks were also quite large as in the surface layers.

Modern fisheries studies carried out along the Gulf coast of Saudi Arabia indicate a very similar range of taxa (Chapter 3.3). Commercially important fishes resident on the reefs included groupers (McCain et al. 1984). It was also noted by Hull (1979) that groupers were common along the coast, and that they were particularly concentrated in certain depths between 20-50m on shell, gravel and corraline bottoms. Jacks (*Carangidae*) were also mostly concentrated in the 25-50m depth band. Comparatively few species of jacks were caught by this survey perhaps because it was done at night. At Dosariyah, *Carangoides* was recorded in the surface layers and trench 5, and in trench 7, this genus was present as well as both *Gnathanodon* and *Trachinotus*. All these fish may be caught however in shallow inshore waters near coral reefs. McCain et al. (1984) noted that *Carangoides bajad* was a transient visitor on reefs in the area, and that jacks were often seen feeding over the reefs. The peak abundance of resident fishes on the Saudi Arabian reefs was during May, peaking by September, the abundance of fishes declining on all surveyed reefs from October onwards and during the winter months (McCain et al. 1984: 112). Available landing statistics for fish caught in Saudi waters during 1977 suggest that mackerel (*Scomberomorus* spp.) form 25% of the annual weight of the catch, followed by emperors, jacks and groupers (Morgan 1985). No mention is made of tuna forming an important percentage of the annual catch. It is curious that no mackerel bones were identified amongst any of the Dosariyah remains. It is unclear whether this is due to the fact that their bones may not be so well preserved as tuna, or whether this may be due to other factors (cf. 6.4.6. below). The detailed habitat survey carried out by Basson et al. (1977) suggests that the taxa represented at Dosariyah came from sandy beach, subtidal mud and sand, sub-tidal rock, coral reef and open water habitats.

6.6.3. Iran

The recently studied archaeological fish bone assemblage from the Sasanian to early 16th century Great Mosque at Siraf (Chapter 4.1.4. – 4.1.5) represents the only recent attempt to provide a detailed examination of fish exploitation on the Iranian side of the Gulf (Badstöber 2000). This study highlighted the importance of particular taxa like sea catfish (*Ariidae*), the king soldierbream (*Argyrops spinifer*), and the silver grunt (*Pomadasys argenteus*). As details of the recovery procedure are not presented in any detail, it is not clear if the low quantities of some smaller species are due to recovery bias. *Argyrops* is one of the largest seabream occurring within the Gulf and as it is mostly represented by hyperostotic neurocranial fragments (Badstöber 2000: 40, tab.ll), this may partly be an effect of their differential preservation. Nevertheless, these particular fish are all more commonly observed in the few modern studies which have been carried out of the Iranian Gulf coast fauna (Blegvad 1944; Kuronuma and Abe 1986). This is due to the fact that much of the sea bottom in this area is mud (Figure 3), a habitat favoured by such species. The fact that a larger range of jacks and scombrids is recorded at Siraf may reflect the fact that deeper waters are much closer on the Iranian side of the Gulf (Figure 2), plus the fact that other cultural factors like trade may be playing an important role. A number of the larger jack species like *Carangoides* and *Scomberoides* were represented by hyperostotic neurocrania, so this again may be exaggerating the apparent importance of these species, if poor preservation and recovery has affected the assemblage.

6.6.4. Bahrain

A number of archaeological fish assemblages have been investigated from Bahrain (Chapter 4.1.1 and 4.1.2). The recently published assemblage from the site of Al Markh, dating to around 4000 BC, represents one of the largest collections of fish bones to be analysed to date from the region (von den Driesch and Manhart 2000). The careful recovery of bones on the site using 4mm and 1.5mm sieves resulted in the collection of a large quantity of fish bones. Most of the material studied, however, was only the >5mm fraction. Differences between the upper and lower deposits at the site are probably due to poor sample size and the fact that more material in the lower deposits was wet sieved. Seabreams overwhelmingly dominated the assemblage. Large quantities of both cranial elements and vertebrae were noted. All age groups of *Rhabdosargus* and *Acanthopagrus* were noted suggesting that the spawning grounds of these species were located in the shallow sandy bottomed coastal waters of Bahrain and in particular along the coast of Al Markh (von den Driesch and Manhart 2000: 61). Groupers were represented by both cranial elements and vertebrae, whereas emperor remains largely consisted of only cranial elements. The fact that fine recovery procedure were adopted also resulted in the recovery of other small fish taxa like gizzard shads (*Nematalosa*) and mojarras (*Gerreidae*). Both these types of fish are caught in shallow sandy muddy bottom habitats. Only two tuna (*Euthynnus affinis*) vertebrae were noted amongst the 31,000 fragments identified to family, genus or species. The dominance of seabream particularly in the lower levels at Al Markh makes it likely that these fish were common in the waters near the site. Although it has been suggested that this indicates that reefs may not yet have been sufficiently developed in Bahraini waters by 4000 BC (von den Driesch and Manhart 2000: 62), it may be simply be an effect of the location of Al Markh. Most of the best reefs in Bahrain are developed around the north and eastern side of the island. The assemblage from Dalma island (cf. 6.4.6. below) also demonstrates that reefs were clearly already well developed in other parts of the Gulf.

The early 2nd millennium BC Dilmun temple levels at Saar were reportedly dry sieved using a 1mm mesh (Moon and Irving 1997). Despite this fact, no similar small taxa like the gizzard shads or mojarras found at Al Markh were noted, although goatfish, rabbitfish and angelfish were noted. The higher proportions of major species like emperors and groupers may be due to a number of factors such as the different conditions near the site, and the context in which they were found. Barracuda bones surprisingly formed 18% of the total number of bones identified from the major species. No other archaeological site anywhere in the Gulf has such a high proportion of identified barracuda bones. Whether this is connected with some special deposits associated with the temple, or that it simply is a result of differential preservation remains unclear. Whilst the fish assemblage from Saar also suggests that fishing was carried out in shallow sandy waters (e.g. for seabream, emperors and flatheads), the presence of some species like groupers indicates that fishing also took place over reefs.

The early 2nd millennium BC fish assemblage from site 520 at Qalat al-Bahrain was hand retrieved and this is reflected in the low numbers of unidentified remains (Van Neer and Uerpmann 1994: 445). Groupers and emperors were both well represented but the amounts of smaller fish may be underrepresented as a result of the recovery procedure. The assemblage is more similar to that from Saar than Al Markh. Whether the higher percentage of groupers and jacks and lower quantities of barracuda at Qalat al-Bahrain compared with Saar is due to recovery, taphonomic or other cultural factors is unclear. The fact that the larger seabream species present in the Gulf, *Argyrops spinifer*, was the commonest seabream at Qalat may also be an effect of recovery (cf. 6.4.3. above). Tuna was only present at the site in very small quantities although both *Euthynnus* and *Thunnus* were noted.

Comparatively little modern fisheries data is published from Bahrain (Chapter 3.5). One study recognised that the fishes in Bahraini waters were distinct from the northern part of the Gulf but unfortunately does not mention which particular species are specifically collected in the different waters areound Bahrain (Al-Baharna 1986). An underwater survey of reef fishes was carried out during the late spring of 1985 (Smith et al. 1987). A number of the species observed on the shallowest reefs (<7m depth) included some of the species identified at the archaeological sites including jacks (*Carangoides* and *Gnathanodon*), snappers (*Lutjanus*), emperors (*Lethrinus*), seabream (*Acanthopagrus* and *Diplodus*), and angelfish (*Pomacanthus*). Deeper reefs (13-15m depth) also contained jacks, snappers, emperors, seabream, angelfish, and barracuda. A further survey of reefs off the coast of Bahrain was carried out in the summer/early autumn of 1985 (Smith and Saleh 1987). This also identified a similar range of fish in shallow and deeper reefs, barracuda and parrotfish only being observed on the deepest reefs at a depth of 13-15m. This latter study noted the low species richness of the fish fauna compared with other regions of the Gulf. Although none of these studies mentions the important seabream species, *Rhabdosargus*, this is probably largely due to fact that the surveys concentrated on reefs and their immediate environs. Fisheries landing data for Bahrain is available for the annual landings between 1979-83 (Morgan 1985). Seabream are reported to only form between 2-4% of annual catches, but the real amount may be masked by factors such as the category "Perciformes" which accounts for 20-30% of annual landings. This category refers largely however to groupers and emperors. Relatively high numbers of rabbitfish (between 15-24% of annual catch) were caught. These only seem to be present in very small quantities on most archaeological sites in the Gulf. This may be simply a question of recovery or poor preservation of their skeletal remains. No mention is made in these statistics of tuna, although it is reported that mackerels (*Rastrelliger kanagurta* and *Scomberomorus*) formed between 2-6% of annual catches.

6.6.5. Qatar

Three 5th to 4th millennium BC sites have been published in Qatar with fish remains (Chapter 4.1.1.). At Khor FB on the north-east coast of Qatar, the remains consisted almost exclusively of otoliths with very few vertebrae being noted (Desse 1988). Although otoliths are composed of calcium carbonate and generally do not survive well on archaeological sites unless they are fortuitously alkaline or neutral in pH (Wheeler and Jones 1989: 115), in some cases like here they may survive better than other bones because of their different chemical composition. The otoliths came from silversides (*Atherinidae*) and seabream (*Sparidae*). It is interesting to note that silversides are generally considered to be without commercial value in the modern fisheries of the region (Carpenter et al. 1997: 127). They occur in inshore waters, near coral reefs and also in open water, being mostly caught by seines. It has been noted that silversides inhabit shallow bays in dense schools around Qatari waters throughout the year (Sivasubramaniam and Ibrahim 1982). This may explain why they may have been caught if they were readily available. The presence of seabream demonstrates, like at Al Markh in Bahrain and H3 in Kuwait, the preference for fishing in shallow sandy bottom waters. At Khor P otoliths from both these species were also found, as well as otoliths from jacks and groupers, plus a few fish vertebrae (Desse 1988: 161-2). Again, it seems likely that poor preservation has affected the assemblage, judging from the ratio of otoliths to bone fragments. On the southeast coast of Qatar, a small 4th millennium BC fish assemblage has been reported upon from Shagra (Desse 1988: 266). As mostly only vertebrae were noted here along with some cranial fragments and otoliths from groupers and seabream, it seems that the material here is also rather poorly preserved. Although it is stated that sieving was carried out, no precise details are made available. The presence of *Chondrichthyes*, groupers and seabream at Shagra, as at the broadly contemporary sites of H3 in Kuwait, Dosariyah on the Saudi Gulf coast, and Al Markh in Bahrain, confirms that shallow inshore waters including reef areas were exploited.

Modern fisheries data for Qatar (Chapter 3.6), however, demonstrates that seabream only formed 2% of the annual catch by weight during 1980-81 (Sivasubramaniam and Ibrahim

1982). Jacks/trevallies (*Carangidae*) and mackerel (*Scomberomorus*) formed 44% of the total annual catch. It is observed though that the numbers of pelagic species are generally low in Qatari waters (Sivasubramaniam and Ibrahim 1982). This study also noted that a number of sharks and rays were common on the east and north-east coasts during the winter months, and that the goldstriped seabream (*Rhabdosargus sarba*) was more abundant in shallow inshore waters than offshore waters, and was caught during all seasons on the north, northeast and east coasts of Qatar. This may confirms Desse's assertion that a preliminary study of the otoliths revealed no obvious seasonal preference (Desse 1988: 79, 226).

6.6.6. United Arab Emirates – Abu Dhabi coastline

The fish bone assemblages from Dalma, Sir Bani Yas, Liffiyya, Merawah and Balghelam represent the first sites to be analysed from the southernmost waters of the Gulf. These sites can be divided into three main areas: the offshore island of Dalma, Sir Bani Yas island, and the coastal barrier islands of Liffiya, Sir Bani Yas, Merawah and Balghelam.

The largest and most diverse fish bone assemblage retrieved from any archaeological site in the Abu Dhabi region is from the early 5th millennium BC site on Dalma. This may reflect the fact that the site is located on an offshore island surrounded by extensive patch reefs and deeper waters. Most of the modern fish brought to the Abu Dhabi fish market originate from the water to the north and east of Dalma (Mr. Asad Shahin, Dalma co-operative, pers.comm.). The most extensive reefs in the southern Gulf are also concentrated in this area (Figure 4). Comparing the Dalma assemblage with that from broadly contemporary site of Al Markh in Bahrain, where similar recovery methods were utilised, reveals a number of interesting contrasts. A similar range of Chondrichthyes was noted at the two sites, but larger quantities of bones were identified at Dalma despite the smaller sample size. The greater number of identified Chondrichthyes bones at Dalma may just be a result of the better preservation conditions at this site, although it may reflect the different catching methods utilised or habitats targeted. Requiem shark remains were recorded in 20 of the 25 layers (80%) studied from Dalma, and Chondrichthyes remains were found in 7 of the 9 lower levels (78%) at Al Markh, so their frequency of occurrence appeared to be similar, perhaps suggesting that preservation may account for this apparent difference. Only a single fragment was identified to needlefish (*Belonidae*) at Al Markh but this species occurred frequently in the Dalma deposits, being present in 92% of all studied layers. Groupers were present in all the studied levels from Dalma and similarly occurred in a high proportion of the lower levels at Al Markh (78%). Jacks/trevallies only occurred in 22% of the lower levels at Al Markh but were present in 64% of the Dalma levels. Emperors occurred in 67% of the lower levels at Al Markh but 96% of the layers at Dalma. Seabream were common at both sites. *Rhabdosargus* was the major species present at both sites, followed by *Acanthopagrus*. *Argyrops* only occurred in small quantities at both sites. No parrotfish (*Scaridae*) were recorded at Al Markh but they were present in 20% of the studied layers at Dalma. Kawakawa/little eastern tuna (*Euthynnus affinis*) was only represented by two vertebrae from middle sized individuals (ca 60-70cm) in two of the nine lower levels at Al Markh, whereas despite the smaller sample size a much larger number of bones were identified to tuna at Dalma. Tuna bones occurred in 64% of all studied layers at Dalma. Both tuna species, *Euthynnus* and *Thunnus*, were recorded at Dalma, as well as Spanish mackerel, *Scomberomorus*. The presence of parrotfish at Dalma, as well as large groupers and jacks indicates that at Dalma more fishing was perhaps carried out on reefs. Fishing was also carried out in deeper open waters for important pelagic species like tuna and mackerel.

Modern fisheries data suggests that pelagic fish have a marked seasonal occurrence in Qatari waters (Chapter 3.6), and that they are often concentrated in certain areas (Sivasubramaniam and Ibrahim 1982). The highly seasonal occurrence of pelagics was also noted at Dalma (Chapter 3.7.1). It is interesting that these modern fisheries statistics largely refer to mackerel (*Scomberorus* spp.), rather than tuna, which are mainly caught between October to November. In the archaeological assemblage from Dalma, the latter appeared to be more common. It may be simply that the bone structure of mackerel vertebrae means that they do not survive so well as tuna vertebrae.

Fishing carried out by the Nestorian christian monastic settlement on Sir Bani Yas concentrated largely on the procurement of small fish within the shallow waters surrounding the island. Many of the taxa represented are similar to those found in the Umm al-Qaiwain lagoon (Chapter 3.7.2). The occurrence of sea catfish and flatheads suggested that mud and sand bottom areas were fished. Other taxa represented like needlefish, jacks, groupers, emperors and seabream could have all been caught in shallow sand and reef areas around the island. Seabream in particular were of some importance. This does not seem to be just a matter of differential preservation. At the present day, the seabream, *Rhabdosargus*, is amongst the commonest fish caught and eaten on the island (personal observation). The largest fish found at any of the Sir Bani Yas sites were medium-sized sea catfish, jacks (*Scomberoides*) and groupers (*Epinephelus*). Even many of these can be caught quite close to shore, although the occurrence of parrotfish (*Scaridae*) suggested that some fishing was perhaps done over adjacent reefs. Only small quantities of scombrids were observed at two sites (SBY4 and SBY9), suggesting occasional fishing in deeper offshore waters. A curious phenomenon at the main monastery site (SBY9) was the relative abundance of vertebrae from Chondrichthyes. These occurred in 60% of all excavated layers. Although it is difficult to estimate the original size of the fish these come from, as the size of the vertebrae gradually decreases in all Chondrichthyes down their vertebral column, the diameter of all of these was very small. Whether the religious community had a particular preference for eating sharks and rays, or simply that these remains have survived preferentially is unclear. Small Chondrichthyes are still dried whole in the traditional fisheries of the region (Chapter 8.1), so one possibility is that the inhabitants of the monastery retained similar food, allowing them more time for spiritual matters.

The assemblages from Liffiyya and Merawah ($6\text{-}5^{th}$ mill BC site MR1.54, and the pre-Islamic/early Islamic sites of MR6,1, MR6.3 and MR12.3) all pointed similarly to fishing in shallow waters and bays around the islands. A similar range of mostly small fish was identified to the Sir Bani Yas sites. Scombrids were only present in small quantities. The Late Islamic middens excavated on Merawah (MR14, MR15 and MR16) also contained a similar range of taxa but more medium and larger-sized fish were noted. Fishing may have perhaps been carried out in deeper waters over the reefs. Needlefish (*Belonidae*) occurred in significant quantities at all three sites. These are surface dwelling fish which can be caught by casting and trolling on the surface as well as by seines (Randall 1995: 85-7). The stratigraphic sequence in MR16 was of some interest. The surface of the midden was carpeted with the murex gastropod, *Hexaplex kuesterianus*. This inhabits areas on and under intertidal rocks (Bosch et al.1995). Earlier layers contained tuna (*Euthynnus affinis*) and in particular a number of mackerel (*Scomberomorus*) bones. The highly seasonal occurrence of these fish, principally during the winter months, has already been discussed. What we may be seeing here is a sequential exploitation of different resources at particular times of the year.

The Late Islamic period site located on Balghelam island (BG12) was clearly a very specialised site for the exploitation of turtles and Chondrichthyes. This may be something like one of the shark processing sites referred to in later historical sources (Chapter 4.3). Late Islamic fishing communities often set up temporary seasonal camps on islands to target particular resources in this area (Cordes and Scholz 1980; Heard-Bey 1982).

6.6.7. United Arab Emirates – northern region

The fish taxa represented at the 5th millennium BC site at Umm al-Qaiwain, with the exception of tuna (*Thunninae*) are all recorded as being present within the modern lagoon adjacent to the site (Chapter 3.7.2; Table 15). Tuna would have been fished beyond the lagoon in the deeper offshore waters. As three of the tuna bones were associated with a human burial, including a dentary from a large individual (ca 120-130cm), it seems that they may have had a special significance for the inhabitants.

The material from the Iron age site at Ed-Dur North was somewhat similar to that from Umm al-Qaiwain. All taxa represented could similarly have been caught in the nearby lagoon. The small number of scombrid remains indicated however that some offshore fishing may have been carried out. At the nearby main site of ed-Dur, the best represented taxa were tuna, *Euthynnus* and *Thunnus* (Van Neer and Gautier 1993).

In Ras al-Khaimah in the northern Emirates, several sites have now been published. At Kush, the material studied from the Sasanian and Abbasid levels was rather poor, but nevertheless suggested that fishing may have been carried out in the now silted up lagoon adjacent to the site. This picture may change though once the remainder of the fish bone assemblage is available for analysis when the stratigraphic dating has been completed. The Early Islamic levels contained a range of taxa very similar to the already published sites in this region, such as ed-Dur (Van Neer and Gautier 1993), Shimal (von den Driesch 1994), Jazirat al-Hulaylah (Beech 1998), and Julfar (Beech 1998; Desse and Desse-Berset 2000). These assemblages are all characterised by the presence of considerable numbers of pelagic fish including tuna and mackerel, as well as large jacks. Other taxa represented indicate that fishing in shallow inshore areas and reefs was also practiced.

Two fish taxa were present in the Early Islamic levels at Kush which are of particular interest. Rainbow runner (*Elagatis bipinnulata*) has only been identified elsewhere in the

Gulf at the Umm an-Nar–Iron age settlement at Shimal (von den Driesch 1994: 80). This site is located just a few kilometres from Kush. *Elagatis* has also been recorded on the east (Gulf of Oman) coast in the Umm an-Nar levels at Kalba (chapter 5.2.14.1). This fish is a pelagic member of the jack/trevally family, which is normally not found too far offshore (Randall 1995: 183). It is usually found near the surface and can also be seen occasionally over reefs. Although a recent publication has stated that it is "not yet reported from the area" (Carpenter et al. 1997: 162), a specimen was purchased by the author at Ras al-Khaimah fish suq on the 19th April 1998. This came from an individual with a total fork length (TL) of 82cm and weighed 3.7 kg. Rainbow runners can reach up to 120cm, but are more commonly reported around 80cm (Carpenter et al. 1997: 162).

Milkfish (*Chanos chanos*) has only been identified elsewhere in the Gulf from two sites, both located in the northern Emirates. Firstly, the 1st-4th century AD levels at ed-Dur, where it is described as being "rare" within the assemblage (Van Neer and Gautier 1993: 118). Secondly, at the neighbouring settlement site of Shimal (von den Driesch 1994: 80). Milkfish is also present in small quantities at the 3rd millennium BC site at Ras al-Hadd, outside the Gulf down on the Omani coast (Caroline Cartwright, pers. comm.). This species is a pelagic fish which spawns in the open sea, but metamorphosis of the larvae is said to take place in brackish water (Randall 1995: 74). It is a big fish which can attain up to 180cm, but is more commonly around 100cm. Modern records exist for this species being sold in Kuwait and Basra city markets in the northern Gulf (Kuronuma and Abe 1986: 47-8). It is able to tolerate wide fluctuations in salinity and can even venture into freshwater.

Why both these species have not been found on other sites in the region is curious. Whether this is due to some specialists not having reference specimens of these particular species, or whether the bones of these fish do not survive particularly well is unclear. Sivasubramaniam and Ibrahim (1982) reported that milkfish (*Chanos chanos*) was only common off the south-east coast of Qatar during the winter months. Another survey reported that moderate quantities of milkfish were caught during the hotter summer months between May-October 1978 at Khor Fakkan on the east (Gulf of Oman) coast, and during October the same year at Kalba (Ali et. al. 1980). The rainbow runner (*Elagatis bipinnulata*) is also known in the Gulf from UAE waters (Ali et al. 1984; personal observation), despite the fact that some report it as being absent (Carpenter et al. 1997: 162). One explanation might be that the occurrence of both these species within the Gulf is highly seasonal which is why they occur on so few sites, and only on the sites located near to the entrance to the Gulf and on the east (Gulf of Oman) coastline.

Modern fisheries landing data for Ras al-Khaimah during 1982 (Table 16) demonstrates that tuna and mackerel form the greatest weight of the annual catch, followed by jacks/trevallies, with smaller quantities of other fish being caught (Ali and Cherian 1983b). The zooarchaeological data provide a similar pattern. The only major discrepancy is that whereas sardines formed 8% of the weight of the total annual catch in the modern landing data, their importance is almost certainly underestimated at the various archaeological sites due to a combination of poor recovery, preservation and various cultural factors.

6.6.8. United Arab Emirates – East coast/Gulf of Oman

The Iron age settlement at Rafaq is the only non-coastal site in this study. It is interesting that such a wide range of fish taxa were imported to the interior, and that crabs were also transported to the site from the coast (cf. section 6.7.). This demonstrates that provisioning of the interior was already taking place by the Iron age. The previous earliest evidence for fish remains within the interior of the Oman peninsula was the 3rd-4th century AD site of Mleiha (Mashkour and Van Neer 1999). Tuna were apparently common at both sites, along with a range of other inshore species. Bearing in mind their respective geographical locations, it suggests that the Wadi al-Qawr may have acted as a natural east-west corridor for the movement of resources between the Gulf and the east coast. Although it cannot be ascertained for certain whether these fish came from the Arabian Gulf or Gulf of Oman coast, the crab remains from Rafaq (Chapters 5.2.13 and 6.7), perhaps support the idea of an east coast origin for at least some of these imported items.

At Kalba on the east coast, the range of fish taxa represented is very similar to sites in the northern region (cf. section 6.6.7), with pelagic fish like tuna and mackerel and large jacks being of some importance. Both occurred in 50% of all studied samples. However, a number of the jack remains (including *Carangoides*), as well as the king soldierbream (*Argyrops spinifer*), were represented by hyperostotic neurocrania fragments, which may have partly exaggerated the importance of these taxa. Other fishes noted at Kalba indicate that fishing in shallow inshore areas and reefs was also practiced. Too few remains are available in the earlier phases at the site to evaluate the effect of any chronological factors affecting the particular composition of the fauna.

Modern fisheries landing data collected between 1976-9 from Khor Fakkan on the east coast (Chapter 3.7.3), suggested a similar pattern to the landing data from Ras al-Khaimah in the northern Emirates. Tuna and mackerel, followed by jacks/trevallies, formed the greatest percentage of the total annual catch (Ali and Thomas 1979; Ali et al. 1980). A similar picture was observed in the modern landing data from Kalba (Ali et al. 1980).

6.7. Modelling the variability of crab assemblages

Most of the crab remains found within the archaeological sites studied within the Gulf (Chapter 5) belonged to swimming crabs, *Portunus*. Two species occur within this genus in the region, the blue swimming crab (*P.pelagicus*) and the threespot swimming crab (*P.sanguinolentus*). *P.sanguinolentus* is very similar to *P.pelagicus* in appearance and habits, and may well be represented in the material, although where the species could be determined with any confidence, it was always *P. pelagicus* (Peter Hogarth, pers.comm.). The blue swimming crab is associated with shallow shores and lagoons, particularly with sandy bottoms, although it is also common on hard substrates in the Gulf (personal observation). It is reported that it is often caught in the Gulf in brackish waters over mud and sand (Carpenter et al. 1997: 38). Shrimp trawls, seine nets and stake nets are used to catch this species at the present day (*op. cit.*). The maximum width of the carapace of modern examples of this species is up to 20cm. Recent surveys of the invertebrate fauna of the mainland coast of the UAE, as well as a detailed study of the Umm al-Qawain region, both noted that *Portunus pelagicus* was the most frequently encountered species of portunid (Hornby 1997; Al-Ghais and Cooper 1997).

Relatively few crab remains amongst those studied from the Gulf belonged to the mangrove crab, *Scylla*. The only Gulf sites where small quantities were retrieved included the island of Merawah, Umm al-Qaiwain, as well as Kush and UNAR2 in Ras al-Khaimah emirate. Small areas of mangrove still exist at the present day in all these areas. However, the two aforementioned ecological surveys carried out did not record its presence (Hornby 1997; Al-Ghais and Cooper 1997).

A contrasting picture was provided by the crab remains from Rafaq (located 25 km from the eastern coast), and Kalba, located on the Gulf of Oman coast. Here, both sites were dominated by chela fragments from mangrove crabs (*Scylla*), with only small quantities of

Portunus. The genus *Scylla*, previously regarded as being monospecific (*S. serrata*) has recently been split into a number of species (Peter Hogarth, pers. comm.). From its geographical distribution, Gulf specimens would be expected to be *S. serrata* (*sensu stricto*). This species inhabits muddy bottoms in brackish water along the shoreline, mangrove areas and river mouths. It can grow to a weight exceeding 2kg (Heasman and Fielder 1983). Some of the crabs were from extremely large individuals. The overwhelming bulk of the material was composed of portions of chelae or of walking legs, with other components virtually unrepresented. This may be partly a result of taphonomic processes. Chelae, especially the 'fingers' are much more heavily calcified than other parts of the exoskeleton. Early disintegration of crab exoskeletons is largely driven by the rate of disappearance of the organic matrix rather than the mineral content (Schäfer 1972). It has also been demonstrated experimentally that there is a taphonomic bias in favour of crab fingers (Plotnick et al. 1988). Nevertheless, the total absence in the *Scylla* material of any fragments that could be assigned to carapace is surprising. It is possible that the Kalba *Scylla*-eaters may have removed the chelae for transport. As *Scylla* is also found at Rafaq, this seems to be a distinct possibility. Another possibility is that they may have harvested chelae from live crabs, returning the remainder of the body to the mangroves, as is currently the practice in the West African fiddler crab *Uca tangeri* fishery (Oliveira et al. 2000).

Scylla serrata and *Portunus pelagicus* are still the main crab species caught for food in the Western Indian Ocean region (Guinot 1966). Interestingly in the Gulf states at the present day they are largely not eaten by the native coastal communities due to religious taboos, although they are consumed in some numbers by expatriate workers (Carpenter et al. 1997: 36-40). In the United Arab Emirates the majority of crabs sold in the fish markets are *Portunus pelagicus*, with no *S.serrata* being sold (personal observation). This may be due to a number of factors, e.g. mangrove areas may be less extensive now than they were in the past, and mangrove areas are not currently intensively exploited because some of them are designated protected areas. The Kalba mangroves are now a protected reserve as they form the largest area of mangroves anywhere along the UAE Gulf and eastern coasts. It would be worth in the future investigating these mangroves to check for the presence of this species, and to compare modern examples with this archaeological material. Recent surveys of crabs along the Emirates coast have not noted the presence of this species (Al-Ghais and Cooper 1997; Hornby 1997). Whether this is simply due to survey biases such as inadequate sampling of mangrove areas is unclear.

Of the other crab remains represented on the sites, *Ocypode* is unlikely to be present as a food species. These crabs are very small and agile, and difficult to catch! Given that they can also forage up to several hundred metres from the sea, even into desert terrain, it is possible that they may have arrived on the archaeological sites by themselves (Peter Hogarth, pers. comm.).

6.8. Modelling the variability of fish assemblages in the Arabian Gulf and Gulf of Oman

In this section the overall variability of archaeological fish assemblages within the Arabian Gulf and Gulf of Oman will be discussed. Four methods will be utilised to do this:

(1) Percentage sample presence (O'Connor 1989: 196), sometimes also known as the "relative frequency method"

This is based upon the number of times a particular taxon occurs in all the studied samples from a particular site. Thus, if groupers occur in 5 out of a total of 10 samples with identifiable fish remains, then a score of 0.50 (i.e. 50%) is achieved. Examination of the percentage sample presence of fish taxa at all the studied sites is a useful means of considering the overall variability of these assemblages. This method partly overcomes the problem of "visibility" between different taxa. Whilst some families and species may be reliably identified and distinguished by a number of different elements, others may be less easily recognised. This method also counteracts the swamping of the data by many specimens of a particular species thereby artificially inflating its relative importance.

(2) Ecological diversity indices

Shannon-Wiener and Simpson diversity indices were calculated using Hans Hillewaert's "Custom functions for biologists", a set of customised add-in functions for Microsoft Excel97, Windows 95 operating system (source – URL: http://www.dvz.yucom.be). Indices were calculated on the basis of the number of identified bones (NISP) identified to each taxonomic category (family, genus or species). Whilst NISP values are not ideal they facilitated the comparison of the sites recorded in this present study with already published assemblages from the region. The data used in this analysis are summarised in Appendix 8.

Using diversity indices allows one to incorporate both diversity and evenness either separately or together (Pielou 1975; Magurran 1988). The Shannon-Wiener diversity index (H') incorporates both diversity and evenness using relative abundances. Simpson's index (Si) is the probability that two individuals picked at random will be the same species and is a useful measure of how individuals in a sample are concentrated into a few species (Evans and O'Connor 1999). Another diversity index which has been used in bioarchaeology to examine beetle samples is Fisher's alpha (Kenward 1978). These indices have been criticised by some neoecologists (Price 1975; Gee and Giller 1991) and environmental archaeologists (Evans and O'Connor 1999). They are used here simply as an illustrative tool to explore the data, not forgetting that variable taphonomic conditions and recovery methods have affected the archaeological assemblages within the study region.

(3) Cluster analysis

Cluster analysis was performed using the following software program, Statistica for Windows v.4.5 (Statsoft, Inc. 1993) on a Windows 95 operating system. Joining (tree clustering) was made using Ward's method as the amalgamation (linkage) rule. Linkage distances are expressed as percent disagreement. Missing data were casewise deleted. The data used for this clustering were presence/absence data for each taxonomic category (family, genus or species) at each of the archaeological sites, with a value of "1" being assigned for presence and "0" for absence.

Cluster analysis has a long history in taxonomy and in community ecology (particularly in vegetation classification). It is often now used for molecular sequence analysis (Dytham 1999: 186). In archaeology it has often been used to discuss the typology of objects (Orton 1980: 46-64). One example where it has been used in bioarchaeology is to examine the degree of similarity between animal bones on medieval sites in north Germany (Benecke 1988). It has been little used in the regional comparison of fish assemblages.

(4) Renkonen's percentage similarity

Renkonen's percentage similarity was calculated using Hans Hillewaert's "Custom functions for biologists", a customised add-in for Microsoft Excel97, Windows 95 operating system (source – URL: http://www.dvz.yucom.be). This analysis was carried out using the number of identified bones (NISP) identified to each taxonomic category (family, genus or species) from every site. Each site was compared against one another to produce a similarity matrix.

Wolda (1981) has compared various similarity indices with simulated data with variable sample size and diversity. Of all the various indices which exist one of the simplest and most robust is Renkonen's percentage similarity (Evans and O'Connor 1999: 175; Wolda 1981).

6.8.1. Percentage sample presence – results

Chondrichthyes, particularly requiem sharks, occurred more frequently in site assemblages located in the northern, western and southern regions of the Gulf, as opposed to those in the northern Emirates and on the east (Gulf of Oman) coast (Table 164). Milkfish (*Chanos chanos*) only occurred at one site, located in the northern Emirates. Sea catfish (*Ariidae*) were more common in northern Gulf. Needlefish (*Belonidae*) were common at the Abu Dhabi coastal sites, particularly on the islands of Dalma and Merawah. Groupers occurred more frequently in the sites located in the northern, western and southern regions of the Gulf, as opposed to those in the northern Emirates and on the east coast. Jacks/trevallies (*Carangidae*) were important in all regions, but certain species like the rainbow runner (*Elagatis bipinnulata*) only occurred in the northern Emirates and on the east coast. Emperors (*Lethrinidae*) were present in all regions but were especially common on the Abu Dhabi coastal sites (Dalma, Sir Bani Yas and Merawah), as well as at Umm al-Qaiwain in the northern Emirates. Seabream (*Sparidae*) occurred in all regions and were particularly common in the northern, western and southern Gulf, as well as at Umm al-Qawain and the Early Islamic levels at Kush in the northern Emirates. Parrotfish (*Scaridae*) was only recorded on the western coast, Abu Dhabi coastline, at ed-Dur north in the northern Emirates. Barracuda (*Sphyraenidae*) was recorded in all regions apart from the northern

Gulf. Mackerel (*Scomberomorus* spp.) was only observed in the southern Gulf on the islands of Dalma and Merawah, in the northern Emirates (at Umm al-Qaiwain and Kush), and at Kalba on the east coast. Tuna (*Thunninae*) was present in all regions but was particularly common in the western region (at Dosariyah) and on the Abu Dhabi coastline at Dalma, as well as in the northern Emirates (e.g. Kush) and on the east coast.

6.8.2. Sample size and ecological diversity indices - results

One problem in comparing these assemblages is the variability in sample size between sites. Table 165(a) summarises the sites examined in this present study, and Table 165(b) those from already published sites. There is a clearly a relationship between the numbers of identified genera and the total number of identified bones (Figure 115-116). Even allowing for the fact that some of the differences between sites are purely due to sample size, there still appears to be a marked difference in the relative diversity of different sites. Using the Shannon-Wiener and Simpson ecological diversity indices (Figure 117 and Table 165a,b), it is clear that there is considerable variation in the diversity of sites with similar-sized samples. If one considers, for example, only the sites with more than a thousand identified bones, then sites like Kuwait (H3), Siraf, Dalma, Qal'at al-Bahrain, Saar, Julfar and Shimal all have relatively high diversity (Shannon-Wiener H' = between 2.48 - 3.93; Simpson Si = between 0.76 – 0.91). In contrast, sites like Dosariyah Trench 1, Al Markh and Sir Bani Yas site SBY9, all have relatively low diversity (Shannon-Wiener H' = between 1.40 – 1.94; Simpson Si = between 0.38 – 0.57). The site with the largest sample size in the whole region, Al Markh in Bahrain (von den Driesch and Manhart 2000), where more than 16,000 fragments were identified, had a comparatively low diversity despite the intensive sieving program during the excavation.

6.8.3. Cluster analysis - results

Clustering of the presence versus absence of particular taxa at all sites separated the data into two main groups (Figure 118). This clustering did not appear to be on any obvious chronological basis but there is a slight tendency towards the grouping of sites from either similar geographical regions or with similar environments.

Group 1 included all the various separate phases at Siraf on the Iranian Gulf coast, Al Markh from Bahrain, as well as Julfar (French excavations) and Shimal, both from the northern Emirates. Group 2 contained the remainder of the sites, subdivided in two further groups. The first subgroup included Khor P, Sir Bani Yas (SBY2, SBY4 and SBY7), Liffiyya, Merawah (MR1 and MR15), Kush (phases 1 and 3), UNAR2, Shimal 602, and Kalba (phases 1-2). If one excludes the sites with less than 5 identified genera, this leaves just Khor P, Sir Bani Yas (SBY2 and SBY4) and Merawah (MR15). The second subgroup included Kuwait, Failaka (sites F5 and F6), Dosariyah (surface, plus trenches 1, 5 and 7), the Saar temple, Qal'at al-Bahrain, Dalma, Sir Bani Yas (SBY9), Merawah (MR6.1, MR6.3, MR14 and MR16), Balghelam, ed-Dur North, Umm al-Qaiwain, Julfar (Japanese excavations), Kush (phase 2), Jazirat al-Hulayla, Mleiha, Rafaq, Kalba (phases 3, 4 and 5-7).

The same presence/absence data was then examined grouping together contemporary sites from the main chronological periods represented. Clustering of the 5th-4th millennium BC sites (Figure 119). produced two main groups: Al Markh and then all the other sites. This latter group was subdivided into two main subgroups: (a) Khor P, Merawah (MR1) and Umm al-Qaiwain, and (b) Kuwait, Dosariyah and Dalma.

Clustering of the 3rd-1st millennium BC sites (Figure 120) produced two main groups: Shimal and then all the other sites. This latter group was subdivided into two main subgroups: (a) Qal'at al-Bahrain, ed-Dur north, Rafaq and Kalba (phases 3 and 5-7), and (b) Failaka (F6), Saar temple, UNAR2, Shimal 602 and Kalba (phases 1-2).

Clustering of the Sasanian, pre-Islamic and early Islamic sites (Figure 121) produced two main groups: (a) Siraf (phases 1A-B) and then all the other sites. This latter group was subdivided into two main subgroups: (a) Sir Bani Yas (SBY2, SBY4 and SBY7), Kush (Phases 1 and 3), and Mleiha, and (b) Failaka (F5), Sir Bani Yas (SBY9), Merawah (MR6.1, MR6.3, MR12.3), Kush (phase 2) and Jazirat al-Hulaylah.

Clustering of the mid-late Islamic sites (Figure 122) produced two main groups: (a) Liffiya, Merawah (MR14, MR15, MR16), Balghelam and Julfar (Japanese excavations), and (b) Siraf (phases 3-4) and Julfar (French excavations).

There appeared to be a slight tendency towards the grouping of sites from similar geographical areas or environments, but clustering was also affected by sample size, as a greater number of taxonomic categories were present at some sites.

6.8.4. Renkonen's percentage similarity - results

The similarity matrix resulting from the Renkonen's percentage similarity analysis of NISP data from the various archaeological sites also suggested that sites were principally grouped according to geographical areas or similar environments (Table 166). The sites are listed in this table in geographical order from Kuwait in the far north of the Gulf, down to Kalba on the east (Gulf of Oman) coast. Grey shaded cells indicate values of > 0.50. Kuwaiti sites are generally more similar to sites located on the Saudi Arabian coast and in the lower Gulf on the Abu Dhabi coastline, than to the northern Emirates and east coast. Siraf on the Iranian Gulf coast was most similar to sites in the northern Emirates and on the east coast. The Saudi Arabian assemblages from Dosariyah were most similar to sites located in Bahrain, Qatar, the Abu Dhabi coastline and Umm al-Qawain in the northern Emirates. The presence of tuna in the surface levels and trench 5 at Dosariyah accounted for its similarity to Kush (phase 2) in the northern Emirates and Kalba (phases 2 and 4) on the east coast. The Bahraini site of Al Markh was closest to sites in both Qatar and on the Abu Dhabi coastline. Saar temple and Qal'at al-Bahrain were both closest to sites on the Abu Dhabi coastline and on the east coast. Khor P in Qatar was most similar to sites located on the Abu Dhabi coastline, than to the northern Emirates and east coast. Dalma was more similar to the nearby assemblages from Sir Bani Yas and the Abu Dhabi coastline than to sites located in the northern Emirates and east coast. The assemblages from the Nestorian courtyarded villas on Sir Bani Yas (SBY4 and SBY7) were similar to Liffiyya and Umm al-Qawain, whilst the monastery (SBY9) was closest to Balghelam in the eastern Abu Dhabi region and Shimal 602 in the northern Emirates. In the case of the monastery, this was due to the high frequency of Chondricthyes. The pre- and early Islamic sites on Merawah (MR6.3 and 12.3) were most similar to the assemblages from the Saar temple and Qalat al-Bahrain. The Late Islamic sites (MR14-16) on Merawah were similar to one another but not to many of the assemblages from other sites, being quite distinctive because of the presence of large numbers of needlefish bones. Sites located in the northern Emirates like Julfar, Kush and Jazirat al-Hulaylah (with the exception of the already mentioned Umm al-Qaiwain site) were more similar to Siraf on the Iranian coast, as well as Kalba on the east coast.

The principal contrast which is drawn out by this analysis are sites which have assemblages dominated by shallow water and reef species, sites with marked quantities of Chondrichthyes and sites with higher numbers of pelagic fishes, particularly tuna and mackerel as well as large jacks. Assemblages in much of the northern, western and southern Gulf consisted of principally shallow water and reef species, although both Dosariyah and Dalma also had notable quantities of tuna. The few sites dominated by Chondrichthyes were the monastery on Sir Bani Yas (SBY9), Balghelam and Shimal 602. In the case of this latter site, the sample only consisted of a few poorly preserved fragments so this may just be incidental. However, the consumption of Chondrichthyes at the monastery, and the apparently specialised processing site on Balghelam (cf. section 6.6.6), may be related to specific cultural preferences or activities. The Umm al-Qaiwain assemblage in the northern Emirates was similar to those assemblages in the northern, western and southern Gulf, i.e. dominated by mainly shallow water species, probably because most fishing was carried out within the local lagoon which provided a similar environment and range of habitats. However, other sites in the northern Emirates, as well as those on the east coast, were characterised by higher numbers of pelagic fish, particularly tuna, mackerel and large jacks/trevallies. These sites were also similar to the various phases from Siraf on the Iranian Gulf coast, suggesting that proximity to deeper water and access to large pelagic species may have been an important factor determining the composition of the archaeological site faunas.

6.9. Summary

How does differential preservation affect our interpretation of the zooarchaeoogical assemblages?

An inherent problem in any study involving fish remains is the question of differential preservation. By adopting a regional approach and studying all the assemblages which were available at the time this research was carried out (1997-2000), it was hoped that at least some of the biases attributable to particular assemblages or small numbers of sites, might be partially negated. Many complex factors can affect fish bone assemblages and unfortunately many of these are not controllable (e.g. Jones 1983, 1986; Walters 1984; Richter 1986, Nicholson 1996; Bullock and Jones 1987; Jones 1987). The morphology of certain fish taxa means that they are more likely to survive than others. Future experimental work, such as trampling experiments (e.g. Jones 1987), could be carried out to create density values for the commonly represented taxa in the region. This would provide another means of assessing the density dependent aspects of the preservation of the various assemblages.

What effect do butchery and processing activities have on the formation of archaeological fish bone assemblages?

Particular butchery or processing techniques may affect which fish and particular elements enter the archaeological record (Belcher 1991, 1994, 1998; Zohar and Cooke 1997). A crucial factor seems to be often the size of the fish and how it is subsequently going to be processed, i.e. fresh or salted/dried. Although low numbers of elements from the branchial region or appendicular skeleton like cleithra and posttemporals may be an effect of some form of butchery or processing activities, such elements do not generally survive so well in archaeological deposits, and are also not so readily identifiable.

Do recovery biases strongly affect the results of this regional study?

Sieving was carried out at all the sites analysed in this study. In the majority of cases this was using 4mm mesh sieves, and in some cases particular sites were sieved to 1mm. The amounts of very small fish are certainly underrepresented, but often this material may not survive in any case because of its fragility. Even sites where all the deposits were sieved using 1mm mesh did not necessarily produce lots of small bones. As the main contrasts between areas are largely dependent on the frequency of occurrence of larger fish like tuna, mackerel and jacks, it seems unlikely that preservation accounts for all the variability.

What problems are there with the identification of the archaeological fish remains?

One of the main problems is having an adequate reference collection for identifying fish remains in this region (Uerpmann 1989; Desse 1995). A major outlay of time was involved in the initial phase of this research project in building an adequate comparative reference collection of Arabian Gulf fishes (section 5.1.1. and Appendix 3). It also took some time to become familiar with the taxonomy of fishes in this region. The literature is often confusing and full of taxonomic contradictions. Some zooarchaeologists are bolder than others in identifying material to a particular species but this often hides taxonomic ignorance. A major difficulty is the identification of small Perciformes vertebrae. In this study the diameter of the centrum of all reasonably complete vertebrae was measured, so that at least if they were not identified some idea could still be provided of their relative size and contribution to the overall fauna at each site.

What problems are there in using modern fisheries data?

As much of the modern fisheries data are based on commercial landings at harbours and fish markets throughout the region, this information is often only at a fairly crude level, and is sometimes only provided in almagamated form. Bycatch is generally ignored, so a false impression may be given of the relative abundance of particular taxa in some regions (e.g. sea catfish are reported to be common in the northern Gulf, but are seldom exploited in the commercial fisheries). The few underwater surveys which have been carried out have provided useful information concerning the habitat preferences of fishes in the region (Basson et al. 1977; Downing 1987; Smith and Saleh 1987). These surveys have their own biases towards less cryptic species.

Can we use various ecological modelling techniques to discern meaningful patterns within the study region?

Percentage sample presence (O'Connor 1989: 196), sometimes also known as the "relative frequency method" partly overcomes the problem of "visibility" between different taxa, and counteracts the swamping of an assemblage by a particular species. However, some sites have only a small number of samples so this measure may be less successful in such cases. The ecological diversity indices (Shannon-Wiener and Simpson diversity indices) calculated on the basis of the number of identified bones (NISP) identified to each taxonomic category (family, genus or species) at each site allowed comparison of the present study sites with already published assemblages from the region. Whilst not all specialists record exactly the same anatomical elements from the same taxa in their NISP counts, as most of the assemblages in the analysis were recorded using the same protocol (Chapter 5.1.4), it was felt to be justified. Cluster analysis can be usefully applied in bioarchaeology to examine the degree of similarity between animal bones assemblages (e.g. Benecke 1988). It has been little used in the regional comparison of fish assemblages.

Renkonen's percentage similarity is one of the simplest and most robust means of comparing similarity between samples (Evans and O'Connor 1999: 175; Wolda 1981).

Cluster analysis does not produce any obvious clustering on a chronological basis but there is a slight tendency towards the grouping of sites from either similar geographical regions or with similar environments. Even allowing for the fact that some of the similarities or differences between sites are purely due to sample size, there still appears to be a marked difference in the relative diversity of different sites. Using the both the Shannon-Wiener and Simpson ecological diversity indices it is clear that there is considerable variation in the diversity of sites with similar-sized samples. Percentage sample presence and Renkonen's percentage similarity seem to suggest a clearer regional pattern within the dataset. The principal contrast which is drawn out by this analysis are sites which have assemblages dominated by shallow water and reef species, sites with marked quantities of Chondrichthyes and sites with higher numbers of pelagic fishes, particularly tuna and mackerel as well as large jacks. Assemblages in much of the northern, western and southern Gulf consisted of principally shallow water and reef species (with the exception of Dosariyah and Dalma). Chondrichthyes were frequent at two sites on the Abu Dhabi coastline, which may represent specific cultural activities or episodes. Sites on the Iranian Gulf coast, in the northern Emirates (with the exception of Umm al-Qaiwain), as well as those on the east (Gulf of Oman coast) coast, were characterised by higher numbers of pelagic fish, particularly tuna, mackerel and large jacks/trevallies. These data mirror to a great extent the present day composition in the modern fisheries data for these regions (Chapter 3).

It is interesting that the archaeological crab remains to some extent also highlight the differences between within the Gulf and outside the Gulf on the east coast. Further work is required though to check the modern distribution of the mangrove crab (*Scylla*) along the United Arab Emirates coastline.

The following chapter will go on to consider the mobility of the inhabitants of the Arabian Gulf and Gulf of Oman, and the role of transhumance and seasonality in regional fisheries.

CHAPTER 7.

INVESTIGATING THE SEASONALITY OF FISHERIES IN THE ARABIAN GULF AND GULF OF OMAN

The goal of this chapter is to examine the role of transhumance and seasonality and its interplay with fisheries in the Arabian Gulf and Gulf of Oman.

- What are the major currently accepted models relating to the mobility of interior and coastal populations?
- Can modern fisheries data provide us with any clues towards likely seasonal scenarios?
- Does zooarchaeological data from any of the studied sites provide any evidence for seasonal occupation?

This chapter initially discusses the principal models relating to the mobility of interior and coastal populations in SE Arabia (section 7.1). Modern data relating to fisheries are then examined to evaluate the aforementioned models (section 7.2). Zooarchaeological evidence from the study sites are then investigated (section 7.3). Otolith analysis is discussed as one possible means of determining seasonality in fish remains (section 7.4). The archaeological otoliths encountered during this study are then described (section 7.5). A pilot study on emperor (*Lethrinidae*) otoliths from two archaeological sites is then presented. After outlining the otolith preparation methods (section 7.6), and the results (section 7.7), there is a discussion of previous studies concerning the biology, age and growth of emperors (section 7.8), as well as problems inherent in the interpretation of otolith results (section 7.9).

7.1. Current models

One of the key regional issues connected with the archaeology of south-east Arabia is whether the earliest coastal inhabitants were fully sedentary or practiced a transhumant pattern of occupation along the coasts in the winter moving to their residences in the interior during the summer months. This pattern is well-attested in the historical and recent ethnographic record in south-eastern Arabia but has not yet been proven archaeologically. In a recent review of archaeology in the Emirates it was stated that:

"Whether or not these groups were fully sedentary is unknown. A transhumant pattern of occupation along the coasts in the winter, when fishing and shellfish gathering would have been the main pursuits, and summer residence in the interior, when pastoralism and eventually horticulture, were practised, is entirely feasible and well-attested elsewhere in south-eastern Arabia, if as yet unproven for the prehistoric U.A.E." (Potts 1997: 44).

A recent study of the vertebrate fauna from the early 5th millennium BC site of al-Buhais 18 in the UAE has demonstrated that domestic sheep and goat, as well as cattle, were more important than hunted wild animals within the interior of SE Arabia (Uerpmann and Uerpmann 2000). The kill-off pattern at this site suggests that predominantly old animals were killed there. As there is not any clear evidence for the slaughter of young males at any of the contemporary coastal sites, it has been suggested that these early pastoralists may have occupied the higher elevations of the Hajar mountains during the hotter summer period, where pastures would have been available (Uerpmann and Uerpmann 2000: 48). This recent study states that:

"It is likely that al-Buhais was visited by these peoples in spring. During the hot season they may have moved to the higher areas of the Hajar mountains where, however, no sites of this period have yet been discovered. In winter the same population must have been staying at the known coastal sites where the subsistence was mainly based on shellfish." (Uerpmann and Uerpmann 2000: 49).

Anthropologists such as William and Fidelity Lancaster and others have also observed more recent traditional migration routes for populations along the Omani coastline, as well as in the Northern Emirates in Ras al-Khaimah (Lancaster and Lancaster 1992: 345). A modern study has even mapped traditional migration routes of the Bedouin populations operating along the Abu Dhabi coastline in recent times (Cordes and Scholz 1980).

7.2. Modern fisheries data

The influence of seasonality on regional subsistence strategies is a topic which has been much discussed in the archaeological literature of SE Arabia (e.g. Bökönyi 1998; Cartwright 1994, 1998; Cleuziou and Tosi 2000; Tosi 1986; Uerpmann and Uerpmann 1996, 2000). Unfortunately there has been little critical evaluation of modern fisheries data available for the region, or detailed analysis of zooarchaeological fish remains to assess the various proposed models and hypotheses.

A detailed examination of modern fisheries data from this region (Chapter 3) suggests however that the winter may not necessarily be the best time for fishing for all species, despite the generally accepted model proposed by Potts (1997: 44) and Uerpmann and Uerpmann (2000).

In Kuwait it is reported that the wind directions during December and January make the waters unsuitable for fishing (Kuronuma and Abe 1972). There is a marked seasonal fluctuation in the numbers of fish on Kuwaiti reefs, and many species are more common during the spring and summer (Downing 1987). Many fish emigrate from the reefs during the cooler winter months to deeper less accessible waters.

Knowledge of the spawning periods of the major species may have been an important factor considered by early coastal communities. In the Arabian Gulf many of the fish spawn during April-June (Ali et al. 1984). Sea temperature appears to be a main factor affecting the spawning season. It is generally believed that the gradual rise of the surface temperature from 21 degrees C in February to about 32 degrees C in June, along with the gradual lengthening of days seems to trigger some physiological factors in the fish which induces spawning (Ali and Cherian 1983a,b).

Fishermen may have knowingly targeted particular spawning aggregations at certain times of year in order to maximise their catches. Hussain and Abdullah (1977) report that the peak spawning season of *Epinephelus tauvina* (now known in the taxonomy as *Epinephelus coioides*) occurs in Kuwait around springtime, from February to May. In a further study of groupers in Kuwaiti waters by Abu-Hakima (1987), it was reported that the spawning period of *E. tauvina* (*E.coioides*) occurs between April to May.

In the Egyptian Red Sea between 50-80% of the annual catch of spangled emperors (*Lethrinus nebulosus*) are made during the spawning season between April and July (Sanders et al. 1984). The fish are "easy to catch" during this period, and fishermen target particular areas where the fish aggregate en masse to spawn. This area is almost exclusively fished between April and July (Sheppard et al. 1992: 265).

Some migratory fish have a seasonal behaviour which make them more accessible at certain times of year. In the case of fish like tuna and mackerel this may be indeed during the winter months. In Ras al-Khaimah waters, narrow-barred spanish mackerel

(*Scomberomorus commerson*) were only caught in small quantities during May and June 1982, none being caught in July, 76% of the catches were however made during the single month of December (Ali and Cherian 1983b). At Dalma island in the lower Gulf, 80% of the catches of this particular species are between October to November, and 51% during the month of November alone (Beech 2000). Other pelagic fish such as sardines and anchovies also occur in greater numbers during the winter months (Heard-Bey 1982: 172). However, poor recovery and preservation on archaeological sites, as well as already discussed cultural factors (e.g. their use as fertiliser and livestock feed), means that their presence cannot be effectively assessed from the archaeological remains.

Winter fishing may have targeted seasonal pelagic visitors like tuna and particularly mackerel, but the modern fisheries data suggests that the optimal season for fishing in much of the Gulf was between the late spring to early summer months. This coincides with spawning aggregations of many species.

7.3. Zooarchaeological data

Bones from the Spanish mackerel (*Scomberomorus*) have been recorded at Siraf on the Iranian Gulf coast, at Qalat al-Bahrain, at Dalma and Merawah (MR14 and MR16) in the lower Gulf, at ed-Dur, Umm al-Qaiwain, Julfar and Kush in the northern Emirates, and Kalba on the east coast. Tuna have now been recorded from Kuwait, Siraf, Dosariyah, Saar, Qalat-al Bahrain, Al-Markh, Dalma, Sir Bani Yas, ed-Dur, ed-Dur North, Umm al-Qaiwain, Julfar, Kush, Shimal, Jazirat al-Hulaylah, Mleiha, Rafaq and Kalba. This suggest that at least some fishing may have been carried out during the cooler winter months. The numbers of identified tuna and mackerel bones along with the total numbers of identified bones from all taxa within each of these assemblages can be seen in Figure 123. Sites located near open deeper waters clearly have higher percentages of such remains. Regions with higher proportions of scombrids included Siraf on the Iranian coast, Dalma in the southern Gulf, and the various sites located in the northern Emirates and east Gulf of Oman coast. This does not appear to be simply a question of sample size or recovery, e.g. only two tuna bones were identified at Al Markh out of more than 16,000 identified fragments in the lower deposits at the site, where all excavated layers were sieved to 4mm. At Dosariyah, a much higher proportion of the bones in the surface layers and trench 5 belonged to tuna than in trenches 1 and 7. The differences between these deposits may possibly indicate the disposal of waste resulting from different seasonal episodes at the site. Sample size and differential preservation may account for some of these apparent differences, particularly in the case of the surface material.

If fishing in the Gulf was carried out during the optimal season between the late spring to early summer months, when many of the reef and shallow water species could be targeted, this may explain the low numbers of pelagic fish like tuna and mackerel in some assemblages. At H3 in Kuwait, Al Markh in Bahrain, the sites on Sir Bani Yas, Liffiyya, Merawah and Umm al-Qaiwain in the UAE, fishing largely concentrated on shallow water species living within lagoons and inshore waters. The targeting of spawning aggregations of fish like groupers, emperors and seabream may also have coincided with the exploitation of other marine resources. The harvesting of pearls in the Gulf was predominantly a summer based activity carried out between early June to the end of September (Heard-Bey 1982: 185). As sites located along the Abu Dhabi coast were situated far from the inland oases, the people there could not engage in agriculture and fishing at the same time (as was the case in the northern Emirates and on the east coast). Fishing and pearling became the exclusive occupation of the people inhabiting this region during the Late Islamic period (Heard-Bey 1982: 174). These fishing coastal bedouin mostly consisted of Rumaithat and some Qubaisat, both sub-sections of the Bani Yas tribe. It is possible that this way of life simply represented a continuation from even earlier periods.

7.4. Otolith analysis

Various kinds of evidence can be used to determine seasonality in the archaeological record. In the case of fishes, growth lines in various structures like otoliths, scales and other bony structures have been investigated (e.g. Casteel 1976; Mellars and Wilkinson 1980). However, the study and interpretation of such remains is not a simple procedure and a number of problems exist. It has been demonstrated that in the case of some elements, e.g. nile catfish pectoral spines (Van Neer 1992), it may be only possible to determine the season of death of individuals that were taken during a period of rapid growth. Even though improved microscopic and computer-based methods have been developed to automatically read growth lines and annuli, disadvantages inherent in the growth cycle of the fish may hamper the determination of seasonality (Van Neer 1992: 125).

Although archaeologists have used otoliths in seasonality studies in northern Europe (e.g. Mellars and Wilkinson 1980; Enghoff 1994) and America (e.g. Casteel 1976) comparatively little attention has been paid to their study within sub-tropical and tropical regions. This is probably partly been due to the misconception that such regions do not have such fluctuating seasonal environmental parameters. This is patently not the case for the Arabian Gulf (Chapter 2.1.3).

Until the late sixties attempts to age of coral reef fish by examination of their hard parts had not achieved the success achieved with temperature species (Panella 1980, Longhurst and Pauly, 1987). This failure occurred because it was assumed that most tropical fish species did not produce annual rings, a phenomenon attributed to the fact these fish did not experience marked variation in water temperature between seasons and so generally grew continuously throughout the year (Pannella 1980, Brothers 1987). Formation of annuli rings in fish hard structure had been attributed to either seasonal variation in ambient temperature or physiological changes during the reproductive cycle. Beckman and Wilson (1995), however, has demonstrated that in temperate fish species the deposition of opaque zones in otoliths is controlled by seasonal changes in ambient temperature rather than by reproductive cycles. Recently, similar conclusions have been reached for many reef fish species in different tropical areas: *Lutjanidae* (Johnson 1983; Mason and Manooch 1985; Morales-Nin 1990), *Scaridae* (Lou 1992), *Serranidae* (Ferreira and Russ 1992; Hood and Schlieder 1992), *Holocentridae* (Dee and Radtke 1989), *Sparidae* (Both and Buxton 1997; Smale and Punt 1991), *Pomacentridae* (Fowler 1990), and *Lethrinidae* (Morales-Nin 1988).

Contrary to the views of Wheeler and Jones (1989: 114) that there are "no winter checks in the deposition of aragonite" in otoliths from tropical marine fishes, there are many examples of successful work on otoliths which have been carried in the western Indian Ocean. Some work has already been carried out on Arabian Gulf fishes (Williams 1986; Samuel et al. 1987) as well as elsewhere in sub-tropical and tropical regions (Fowler 1995). This has confirmed that most marine fishes in Kuwait have conspicuous marks on their otoliths. In the case of some species (*Otolithes argenteus*, *Epinephelus coioides* and *Lutjanus coccineus*) these have been validated as representing true annuli (Samuel et al. 1987).

Williams reports that:

"the otoliths of fish living in Kuwaiti waters, where there is a marked difference between winter and summer sea temperatures, show an alternating sequence of growth zones..... In most winter or spring-spawning marine teleosts the nucleus is usually composed of opaque material. This opaque material continues to be deposited throughout the first months of life of the fish, usually until the onset of late autumn or early winter, when the hyaline zone begins to form. Hyaline material is deposited during the next few months, deposition of opaque material beginning again in the late winter or early spring. This seasonal pattern in the growth of the two different types of zone continues each year throughout the life of the fish, although some slight changes may occur in the timing of zone formation as the fish grows older." (Williams 1986: 1).

Most of the demersal fish caught in Kuwait waters begin to grow the opaque zone in the spring of the year (Williams 1986: 12).

7.5. The archaeological otoliths

Otoliths only occurred in significant numbers at three of the archaeological sites studied, namely at the 5th-4th millennium BC sites of H3 in Kuwait, and Umm al-Qaiwain in the UAE, as well as at the 6th-7th century AD monastic site on Sir Bani Yas island (site SBY9).

There was not sufficient time within the scope of this present study to complete a more detailed study of the sea catfish (*Ariidae*) otoliths from the 5th millennium BC site of H3 in Kuwait. It should be investigated in the future whether it might be possible to undertake a special study of these in order to determine the age of individual fish, as well as their possible season of capture. According to a study undertaken by workers from the Mariculture and Fisheries Department of the Kuwait Institute of Scientific Research, the age determination of *Arius thalassinus* otoliths is quite feasible (Samuel et al. 1987: 260). They report that the large spherical otoliths of this species are "easy to read in unburned cross section with transmitted light", although they warn that "...split rings in otoliths of young fish near the nucleus may be confused with annual marks" (Samuel et al. 1987: 260). They report that *Arius thalassinus* has an age range from 0-18 years and that its total length ranges from about 11-79cm. Determination of the age of the fish should therefore be possible for many of the archaeological otoliths. Working out the season of capture may be more problematic. The timing of deposition of opaque and hyaline zones can vary with species, geographical location of stock and age of the fish, although it has been suggested that most of the demersal fish caught in Kuwait waters begin to grow the opaque zone in the spring of the year (Williams 1986: 12). This particular study promisingly reported, however, that satisfactory ageing results were obtained for *Arius thalassinus* and *Arius* spp. (Williams 1986: 15). It is planned that collaborative work will be carried out in 2001 by the author, together with colleagues from the Marine Research Section of the Kuwaiti Institute for Scientific Research (KISR). If validation work can be carried out to determine the seasonal timing of the occurrence of opaque and hyaline bands in *Arius* otoliths in the northern Gulf then we may be able to provide a more precise determination concerning when the fish were caught.

A small number of otoliths were retrieved from the excavations of the Nestorian Christian community living on Sir Bani Yas island. These were from sea catfish (*Ariidae*), groupers (*Epinephelus coioides*), spangled emperors (*Lethrinus nebulosus*) and goldstriped/haffara seabream (*Rhabdosargus* sp.). Most of the otoliths belonged to spangled emperors, and 15 complete well preserved examples were collected from one particular layer (context 44), associated with the kitchen in the east wing of the monastery.

The Umm al-Qaiwain fish assemblage was remarkable in that a relatively large collection of otoliths was recovered during the excavations. This was undoubtedly due to a combination of factors, such as appropriate preservation of the deposits, the effects of burning from the eight discrete hearths, along with the capping of the site by shell midden deposits. There is also fortunately no evidence of widespread destruction by carnivores or rodents leading to their poor survival (Jones 1990). The recovery procedure whereby much of the deposits were sieved using a 1mm mesh also ensured the excellent retrieval of material. Single otoliths were recovered from snappers, grunts and seabream, whilst a couple of otoliths were identified to barracuda. Twelve otoliths from spangled emperors (*Lethrinus nebulosus*) were identified in various layers in the lower deposits. The majority of the otoliths however belonged to pinkear emperors (*Lethrinus lentjan*), seven specimens being recovered from the upper midden deposits and 61 from the lower deposits at the site. The otoliths were identified as being *L. lentjan* rather than *L. nebulosus* because the location of the colliculum (groove) was on one side, rather than nearer to its mid-point as is the case with *L. nebulosus*. This became even clearer once the otoliths had been sectioned.

All the emperor (*Lethrinus lentjan / Lethrinus* sp.) otoliths in the upper midden deposits were from small-sized fish (Table 167). In the lower deposits, a total of 61 otoliths from pink ear emperors (*Lethrinus lentjan*) were noted. Out of these, 54 were complete enough to measure (Figure 124). They were mostly between 6-8mm in breadth and 4-6mm in height, suggesting that many of the fish were probably from similar age classes.

7.6. Otolith analysis – preparation methods

In collaboration with Dr. Mohammed Salem of the Tropical Marine Research Unit in the Department of Biology at the University of York, the emperor otoliths from both Sir BaniYas and Umm al-Qaiwain were all sectioned to examine if their growth rings were well preserved. To begin with a pilot study began by sectioning modern otoliths from 8 individuals of various sizes of *Lethrinus nebulosus*. These were specimens collected during a number of trips to the United Arab Emirates during the months of March-April 1996-7. All the fish were photographed, measured and weighed. Otoliths (*sagittae*) were removed by carefully cracking the ventral side of the fish skull using a sharp pair of pliers, and picking out the otolith using pointed tweezers. This pilot study helped to refine the appropriate sectioning method. It also allowed testing of one of the archaeological otoliths to see if the growth rings were preserved well enough to merit further study. Two earlier unsuccessful attempts had been made to examine the otoliths. One already part damaged otolith was tested by breaking it in half and then exposing its inner exposed section to a flame following the method suggested by Christensen (1964). A second method which was tested was embedding an otolith in a small resin block which was then sectioned using a slow-cutting diamond saw in Prof. Tim Skerry's laboratory, with the assistance of Dr. Nicky Peet, within the Department of Biology at the University of York. The burning method did not produce clear enough results on the archaeological otoliths, although it did seem to produce better results with modern lethrinid otoliths. Sectioning of the otolith once it was embedded in a resin block proved quite difficult as it was difficult during the cutting procedure to check the precise orientation of the otolith within the block and how close the cutting blade was to the nucleus of the otolith.

The following simple largely hand-based preparation method was therefore developed to examine a thin transverse section passing through the core of each otolith. This was achieved by first grinding the otolith anterior apex to the nuclei horizontal plane using a series of increasingly fine grade carborundum sandpapers (800, 1000 and 1200). The ground otolith was then embedded in a drop of polyester resin (CrystalBond 509) on a microscope slide with the ground side facing the glass surface. Then after 15 hours hardening the posterior apex was also ground to the nuclei plane. The section was checked regularly during grinding using a light microscope until best resolution had been obtained. All grinding was undertaken in wet conditions using a controlled speed rotating grinding disk. The otolith sections were then studied using a MEIJI techno binocular polarising microscope in the Department of Archaeology at the University of York. Very clear growth rings were observed. The contrast between opaque and hyaline zones increased when a drop of clarifying medium (clove oil) was placed over the otolith section. For each section the number of continuous annual rings (opaque bands) were counted. The counts were independently repeated after two weeks. When the estimated age differed by one year only, the section was studied carefully again. Sections for which estimates showed two years or more difference were discarded. The outermost ring was recorded and a note was made if it was an opaque or hyaline band in its early, middle or late stage judged in comparison to the ring immediately preceding it. A similar approach was used by Enghoff (1994) to examine gadid otoliths from Ertebølle period sites in Denmark.

7.7. Otolith analysis - results

The eight modern spangled emperor (*Lethrinus nebulosus*) otoliths, all captured between March to April from Abu Dhabi waters, had early to middle-sized opaque increments as their outermost band (Figure 125).

All fifteen spangled emperor otoliths were successfully sectioned from site SBY9, Sir Bani Yas. The majority of the fish were between 1-6 years in age, with a 10 year and 14 year old individuals also being present (Table 168). Most of the otoliths had a middle-sized or late opaque band as their outermost increment. At Umm al-Qaiwain, twelve spangled emperor otoliths were sectioned from various layers in the lower deposits. These mostly came from fish aged between 1-3 years, a single 5 year old individual being present. Again, most of the otoliths had a middle-sized or late opaque band as their outermost increment.

At Umm al-Qaiwain, the four of the seven pinkear emperor otoliths present in the upper deposits were successfully sectioned. Two were from very young fish only 1 year + old, whilst 3 year+ and 7 year+ individuals were also represented (Figure 169). Half of the otoliths had late opaque bands as their outermost incremental band. A total of 55 out of the 61 pinkear emperor otoliths from the lower deposits were successfully sectioned. No individuals older than 7 years+ were noted, as was the case with the upper deposits. The majority of the fish represented were from young fish, e.g. 66% were from 3 years+ or younger fish and 87% were from 5 years+ or younger fish. The majority of these otoliths had middle to late opaque outermost bands (69%), almost half the specimens (43%) having a late opaque outermost band.

7.8. Biology, age and growth studies of emperors (*Lethrinidae*)

A number of studies have already been carried out concerning the biology, age and growth of emperors (*Lethrinidae*) in this region and other sub-tropical and tropical waters.

The spangled emperor (*Lethrinus nebulosus*) is distributed throughout the Indo-Pacific, being recorded in the Red Sea, Persian Gulf, East Africa, southern Japan and Australia. The juveniles stages inhabit either seagrass beds or mangrove stands before moving to coral reef areas. *L. nebulosus* feeds on echinoderms, molluscs and crustaceans. Because of its carnivorous feeding habits, it is very vulnerable to handline fishing (Fishbase 1998). Morales-Nin (1988) studied the age and growth of *L. nebulosus* in New Caledonian using otoliths. Ebisawa (1990) studied the reproductive behaviour of *L. nebulosus* in Okinawan waters in Japan. He described them as multiple spawners, which release several batches of eggs over a long period of time, and spawn in aggregations with no relationship to lunar cycles. Ezzat et al. (1992) have investigated the age and growth of fish in Arabian Gulf waters using fish scales. More recently a detailed study of the age and growth of the spangled emperor, *Lethrinus nebulosus*, has been carried out for the northern Red Sea coast of Egypt (Salem 2000). In this study the validity of using otoliths in ageing *L.nebulosus* was supported by the presence of annual rings in immature fish (sizes <35 cm). This suggested that these rings are not produced during spawning periods, the regularity of the annuli-nucleus distances and very strong positive correlation of otolith radius and fish length also supporting this (Salem 2000). Almost 50% of the male and female specimens examined in this study were fully mature at sizes 35 and 37cm respectively, the percentage frequency of mature individuals rising rapidly with body length thereafter, suggesting that both sexes of *L.nebulosus* become sexually mature at an age of 4 years. The study demonstrated that *L.nebulosus* spawned twice every year three days after the full moon during the period between late April to early June.

The pink ear emperor (*Lethrinus lentjan*) is widespread throughout the Indo-West Pacific, from the Red Sea, Arabian Gulf, and East Africa to the Ryukyus and Tonga (Carpenter and Allen 1989). A characteristic feature of this species is that the posterior margin of the opercle and sometimes the base of the pectoral fin is red. It is a reef-associated, non-migratory fish which inhabits sandy bottoms in coastal areas, deep lagoons and near coral reefs. Juveniles and small adults commonly occur in loose aggregations over seagrass beds, mangrove swamps and shallow sandy areas while adults are generally solitary in deeper waters (Carpenter and Allen 1989). Toor (1963; 1968) studied the biology and fishery of *L. lentjan* in southern Indian waters by studying their length-frequency distributions, otoliths and scales. He recognised two spawning seasons from December to February and June to August, and recognised that occasional spawning may extend beyond these periods. Growth checks were determined to be annual, and back-calculations established that the estimated size of *L. lentjan* after the end of its first, second, third, fourth and fifth years were 15.14 cm, 26.71 cm, 35.34 cm, 42.28 cm and 47.42 cm, respectively (Toor 1968: 618).

Wassef (1991) carried out a comparative growth study of *L. lentjan* in the Red Sea off Jeddah in Egypt. Ages were determined by scale readings and back-calculated lengths up to the seventh year of life for the species. Although the annual range of temperature in Jeddah waters is only 10°C, this study confirmed that an annulus was laid down annually on the *L. lentjan* scales. The time of annulus formation was identified to be during the period July-August, immediately following the reproduction season which extended from April to July. The most frequent observed size classes of *L. lentjan* were from 23-33 cm, which comprised 75% of the fish examined during the study. The majority of fish were aged 2+ (34%), 3+ (34%) and 4+ years (16%). Fish aged 1+, 6+ and 7+ years were less common (10%). The optimal size and condition was attained in May at the beginning of the spawning season. Growth in weight was found to be greatest during the third and fourth year of life.

The only detailed study that has been published concerning the growth and maturity *of L. lentjan* in the Arabian Gulf is that of Ali et al. (1984). According to their study of the species in United Arab Emirates waters, mature ripe (non-spawning) specimens (stage 5) appeared in the catches in February (37.5% of the specimens were at this stage). In March 20% of the specimens were in maturity stage 5. In April and May no mature ripe specimens were seen but in June 82% of the specimens were seen in a mature spent stage (stage 7). In October 54% of specimens were in mature ripe (spawning) stage (stage 6). In all other months the specimens were seen to be in early stages of maturity. These observations indicate that *Lethrinus lentjan* has two spawning seasons in the year, the first season between May and June, and the second season between late September and early October. Mature near ripe (Stage 4) specimens were above 19cm in total length and had a body weight above 100g (Ali et al. 1984: 8). Sea temperature appears to be a main factor affecting the spawning season. The gradual rise of the surface temperature from 21 degrees C in February to about 32 degrees C in June (Ali and Cherian 1983a), along with the gradual lengthening of days seems to trigger some physiological factors in the fish which induce spawning. The average total length of the mature ripe (spawning) specimens examined in October was 24cm with a body weight of 188g. The highest monthly average total length of 43.4 cm and body weight of 1031g were seen in November, and the lowest average total length of 22.6cm and body weight of 165g were seen in July.

Sanders and Morgan (1989) suggest that pinkear emperors (*Lethrinus lentjan*) first become sexually mature at around 3.8 years when they have a mean length of 28.4 cm in the Red Sea/Gulf of Aden area. Carpenter and Allen (1989) noted that this species spawns throughout the year, but peaks once. They report that in the Red Sea spawning occurs mainly in January, April and May, and that at Tuwwal on the Saudi Arabian Red Sea coast it is between April to June.

There is a general consensus that *L. lentjan* spawns predominantly between April to July in both the Red Sea and Arabian Gulf. Past studies of both lethrinid otoliths and scales suggest that an annulus is laid down annually on both structures, and that these rings are not produced during spawning periods. The formation of the annulus is generally considered to be linked to seasonal changes in ambient temperature.

7.9. Discussion

There are a number of problems associated with interpreting the results of the analysis of the Sir Bani Yas and Umm al-Qaiwain otoliths. Detection of the formation of the early hyaline zone may be partly masked by edge effect, i.e. the preservation of the outermost edge of the otolith. This may have led to the underestimation of specimens with hyaline bands as their outermost increment. Attempts were made to rectify this however. All the sections analysed here were examined at two week intervals by independent observers (Mohammed Salem and myself), and any otolith sections where we differed by two years or more and disagreed over the outermost incremental band were discarded.

Another problem is that the larger number of otoliths with middle and late opaque bands as their outermost increment may simply reflect the growth cycle of the fish (Van Neer 1992: 125). A key problem is the interpretation of the hyaline and opaque bands. Not enough work has been done concerning the crosschecking and validation of lethrinid otoliths within the Arabian Gulf. The assumption is made here that the main annuli visible on the otoliths are annual, and that the hyaline band forms predominantly during the cooler winter months. This seems highly probably on account of the previously discussed studies. Nevertheless, to be absolutely sure it would be necessary to undertake a comprehensive study doing tagging, length distributions, a maturity and sex study, as well as preparing sections of otoliths from hundreds of fish at monthly intervals during a whole year. This was beyond the capabilities of this study and in any case was not possible within the time framework of the present research.

The recording of the outermost hyaline or opaque band was made by a rather subjective description of "early", "middle" or "late". These distances could be measured using down the microscope using a graticule, which would produce a more objective description of the data. This could be worth doing in the future if a more detailed study of modern fish is carried out. It was decided however that for the purposes of this pilot study it was sufficient to broadly categorise the final increment. A similar approach was adopted by Enghoff (1994) in a study of gadid otoliths from Mesolithic sites in Denmark, although she sub-divided the outer increment into five separate groups and directly attributed them to seasons (winter/spring, summer, summer/autumn, autumn and winter). Something which is important is that the otoliths from both the sites examined in this study largely came from very young individuals, thereby avoiding many of the problems and pitfalls relating to growth-ring analysis in older fish (Campana and Jones 1992; Monks and Jonston 1993).

Although most of the otoliths at Sir Bani Yas came from juvenile individuals, two of them were from larger adult fish which may have been caught in deeper waters. It was immediately striking that the majority of fish caught at Umm al-Qaiwain were from juveniles which would not have yet been sexually mature. Most of the otoliths had an outermost band which was opaque and of middle to late thickness. The study carried out on otoliths of fish living in Kuwaiti waters found that hyaline zone formed with the onset of late autumn or early winter, and that the growth of the opaque zone generally began in the spring of the year (Williams 1986: 12). The coolest air and water temperatures normally occur between November to December in the Arabian Gulf, which may be the time when this hyaline zone typically forms. The fact that most of the archaeological otoliths have middle to late opaque outermost bands might therefore be interpreted to mean that the fish were caught some time between the spring/summer to early autumn months.

One important factor, which should be taken into account when attempting to understand the Umm al-Qaiwain data, is spawning behaviour and the location of nursery grounds. It is a well-known fact that many lethrinids have a tendency to aggregate in particular locations at certain times of year. Early fishermen would undoubtedly have been aware of many of these cyclical patterns and would have taken advantage of them to target and maximize their catches. One example is along the Egyptian Red Sea coast where *L. nebulosus* aggregates to spawn every year at three well-known reef sites (Salem 2000). The most important spawning ground of *L. nebulosus* in term of population size and fish production is located a reef site known to divers as Jackfish Alley in the Ras Mohammed National Park. Several thousands of fish aggregate every year during the period between late April to early June. Similar important areas also occur in the Arabian Gulf. The nearby Umm al-Qaiwain lagoon area is known to be an important spawning and nursery ground for a number of species which similarly have a spawning season during April to June (Ali and Cherian 1983b; Ali et al. 1984). A modern fisheries survey of the Umm al-Qaiwain lagoon reported that emperors (*Lethrinus* spp.) were found in larval or young stages throughout the year, suggesting that the lagoon was an important spawning area for these fish (Department of Fisheries 1984). Fishing communities may have deliberately targeted the Umm al-Qaiwain lagoon at this time of year knowing that aggregations of such fish would have been an easy catch. Both *Lethrinus lentjan* and *L.nebulosus* are reported as being abundant in a modern fisheries study of the Umm al-Qaiwain lagoon, which noted that they could be caught using beach seines, gill nets, cage traps or by hand line (Table 15; Department of Fisheries 1984).

Elsewhere in the Gulf it has also been observed that the peak spawning season of fishes such as *Epinephelus coioides*, *Pomadasys argenteus*, *Acanthopagrus latus*, *A. cuvieri*, *Otolithes argenteus* and *Pampus argenteus* all have a peak spawning season between February to May (Hussain and Abdullah 1977). A number of different species could have therefore been also targeted.

If the analysis of the pinkear emperor (*Lethrinus lentjan*) otoliths from Umm al-Qaiwain is correct, and most fishing was carried out between the late spring to early autumn months, this contradicts many of the generally accepted models concerning the seasonal mobility of these early inhabitants of the region (e.g. Potts 1997; Uerpmann and Uerpmann 2000). Clearly the previous models which have been presented represent gross over simplifications of what actually went on in the past. Although it is tempting to view this new evidence as confirmation of the existence of specialized groups of fishermen vs. pastoralists operating in south-east Arabia during the 5-4th millennium BC a number of problems remain. It is clear that further work is required to confirm the precise timing and chronological formation of the opaque and hyaline bands in otoliths of these species. This can only be done by a much larger detailed modern study. Clearly early fishing communities had a detailed knowledge of not only the seasonal behaviour of the various types of fish available in the Gulf but also the optimal sites for accessibility to such resources. In a recently published study of the fish remains from al Markh in Bahrain it is noted that...

> "Even if it is not possible to state the exact ages of the fish, the finds include young or immature animals which hatched in the coastal region and remained there for some time until they were large enough to swim to other areas.... juveniles are attested among the bones of Emperor fish (Lethrinidae), which at least indicates the presence of the fish during spawning and thereby limits the time of the fish capture for Al Markh in some respects. The main spawning period lasts from April to July in the Indo-Pacific... It seems almost certain that the fishers of Al Markh, knowing exactly the time and place of spawning, stayed at the site in late spring and early summer in order to fish." (von den Driesch and Manhart 2000: 62).

The fish remains from Umm al-Qaiwain are clearly similar to those observed at Al Markh. Much of the published archaeological literature however persists in citing the general observation that fishing is more successful during the cooler winter months. This is suggested on the basis of modern observations that catches are higher and a more diverse range of fish can be caught at that time of year. Such an argument is used to support the likelihood that coastal sites were occupied during the winter, the occupants following a nomadic life-cycle whereby they then moved into the interior during the spring or into the mountains during the summer. Clearly this hypothesis is no longer completely tenable. It may have been to the distinct advantage of certain groups to remain on the coast to target certain locations for spawning aggregations of fish like emperors and seabream. This presents the fascinating possibility that the origins of the various fishing coastal bedouin tribes occupying SE-Arabia, such as the Rumaithat, may lie far back in antiquity. In the 5th-

4th millennium BC clearly some communities may have stayed on the coast during the summer months whilst others moved with their domestic animals to higher elevations in the interior.

7.10. Summary

What are the major currently accepted models relating to the mobility of interior and coastal populations?

There is an assumption in many current models relating to the inhabitants of SE Arabia that a transhumant pattern of occupation along the coasts in the winter was practiced, the people subsequently moving to their residences in the interior during the summer months (Potts 1997; Uerpmann and Uerpmann).

Can modern fisheries data provide us with any clues towards likely seasonal scenarios?

Modern fisheries data from the Arabian Gulf suggests that although the winter months were a good time to catch certain pelagic species, like tuna and mackerel, the optimal time for many shallow water and reef species was between the late spring to early summer months. This time of year coincides with spawning aggregations of many of the major species represented at the archaeological sites (Abu-Hakima 1987; Hussain and Abdullah 1977; Sanders et al. 1984; Sheppard et al. 1992: 265).

Does zooarchaeological data from any of the studied sites provide any evidence for seasonal occupation?

There appeared to be some regional variation in the occurrence of scombrid remains. They represented a high proportion of all identified remains on the Iranian Gulf coast, as well as at the various sites located in the northern Emirates and on the east Gulf of Oman coast. Dalma island stands out amongst the sites located in the southern Gulf, having a higher proportion of scombrids. This suggests that at least some fishing may have been carried out during the cooler winter months. If fishing in the Gulf was mainly carried out during the optimal season between the late spring to early summer months, when many of the reef and shallow water species could be targeted, this may explain the low numbers of pelagic fish like tuna and mackerel in some assemblages. The targeting of spawning aggregations of fish like groupers, emperors and seabream may have coincided with the exploitation of other marine resources, such as the harvesting of pearls. A pilot study on archaeological otoliths from Sir Bani Yas island and Umm al-Qaiwain reveals that clear increments are preserved. If one accepts that the main annuli visible on the otoliths are annual, and that the hyaline band forms predominantly during the cooler winter months, then the majority of the fish were from young immature individuals and were caught between the spring/summer to early autumn months. Further modern work is urgently required to validate the precise timing and formation of opaque and hyaline zones, as well as the growth rate cycles of emperors in this region.

The following chapter will consider the potential of using ethnographic and zooarchaeological data to identify fish processing sites, dried fish products, and possible evidence for fish storage and trade in the archaeological record of the region.

CHAPTER 8.

IDENTIFYING FISH PROCESSING, DRIED FISH AND POSSIBLE EVIDENCE FOR FISH STORAGE AND TRADE IN THE ARABIAN GULF AND GULF OF OMAN

The goal of this chapter is to examine if traces of fish processing, dried fish, and possible evidence of fish storage or trade can be detected in the archaeological record of the region.

- Can ethnographic data relating to fisheries in the United Arab Emirates provide any useful analogues for understanding archaeological fish assemblages?
- What zooarchaeological evidence is there for fish processing in the past?
- Can dried fish be detected in the archaeological record?
- Is there any evidence for the import/export (?trade) of fish products?

This chapter firstly considers modern ethnographic data relating to fisheries from the United Arab Emirates and Oman (section 8.1). Following this there is an evaluation of the zooarchaeological data which may be connected with particular processing or storage activities (section 8.2). The limitations of these data are then discussed (section 8.3).

The historical evidence relating to fisheries has already been discussed (Chapter 4.3). Whilst Sumerian and Assyrian sources may mention the specific import of sea fish to Mesopotamia, some of which may have originated from the Arabian Gulf (e.g. Salonen 1970), it is a different matter identifying specific production/processing sites. Later historical sources clearly describe some of the activities carried out by the coastal communities of SE Arabia, including the capture of sardines (and possibly anchovies) for human consumption as well as livestock feed and fertiliser.

However, it is extremely difficult identifying specific fish processing sites in the archaeological record. Although post-holes and gulleys have been identified at a number of archaeological sites (e.g. at Dalma site DA11), which may relate to wooden structures supporting racks or lines for the drying of fish, the interpretation of these cannot be certain. One possibility is to utilise ethnoarchaeological studies of procurement and butchery from similar environments to those in which the archaeological remains are recovered. Procurement strategies are inherently connected with fish behaviour and size (Akazawa

1969; Hiryana et al. 1952). If the same species used in the past are being caught at the present day within similar environments then stronger analogies can be developed.

8.1. Ethnographic data relating to fisheries in the United Arab Emirates

In the UAE, fish drying structures can still be seen in use at the present day on the island of Merawah (personal observation). Here, a number of wooden posts support a "washing line" type arrangement with fish being hung over or tied onto the line. The fish usually dried on these racks include small jacks (*Carangidae*) and strips of shark flesh (probably from requiem sharks, *Carcharhinidae*). Very little archaeological traces remain of such processing activities because of the simple methods employed.

Small fish like sardines and anchovies are usually simply spread on the ground to be sun dried, before being shovelled into sacks for transportation. Large areas of the island of Jazirat al-Hulaylah in Ras al-Khaimah emirate, as well as beaches, mud flats and even asphalt roads in Fujairah and Kalba on the eastern UAE coastline in the Gulf of Oman are often covered with such fish (personal observation). A lot of these fish are destined not for human consumption but for use as camel fodder and fertiliser.

Medium to large fish are usually simply split open into "butterfly fillets" and allowed to dry in the sun on the ground. After anything between 24 hours to a few days the fish can simply be picked up, as they become as hard as a board, and can be banged against one another to knock off excess flies. This method is still used at the present day on Dalma island for the drying of large jacks/trevallies and tuna (personal observation). These were all split ventrally leaving all the vertebrae intact within the fish. Skulls were usually split, and the only other bones damaged were some parts of the branchial and appendicular skeleton.

Similar traditional processing methods have been observed on the Makran coastline in Pakistan (Belcher 1991, 1994, 1998) and in Panama (Zohar and Cooke 1997). This work has already been discussed (Chapter 6.2). Both these studies also confirmed that the size of the fish was an important consideration determining how it was subsequently processed.

Fish and dried fish still form an important resource which is transported to the inland oases in the UAE (Iddison 1998). At the Al Ain fish suq a variety of preserved fish, known locally as "cheseef", are sold. These include mostly dried fish ("Mal-lah"). The most common type sold in the Al Ain suq are anchovies ("gashr"). Dried shark ("awal") is the next most common dried fish sold. This is usually sold in the form of strips ca. 10 cm long which are tied together in bundles or sold in a plastic bag. Other fish which are salted and dried for sale as whole split fish include tuna (*Euthynnus* and *Thunnus*), Spanish mackerel, known locally as "kingfish" (*Scomberomorus*), and queenfish (*Scomberoides*). Tuna is also sometimes sold cut into smaller pieces. A great deal of narrow-barred spanish mackerel, as well as tuna, are also prepared by being wet salted in barrels. These can be seen in Abu Dhabi, Dubai, Ras al-Khaimah and Fujairah fish markets. Whole small dried seabream (*Sparidae*), dried shellfish and shrimps were also observed in the Al Ain fish suq (Iddison 1998: 6). Similar dried fish products are also sold in the large fish market at Dubai (personal observation).

In neighbouring Oman, small stone cairn structures were built on the shoreline until recent times for the storage of dried fish (Costa 1988). Nets are put over the top of the circular cairns to protect the small dried fish being stolen by birds. Although similar structures are found in the archaeological record throughout the region, these are usually identified as huts or burial tombs. The Omani traditional fishing stations are usually regularly cleaned out so little trace is left of their original function once all the dried fish have been removed.

8.2. Zooarchaeological evidence

An inherent problem in using the bone and body part distribution of fish to infer a difference between consumer and production sites is the question of bone survival. This has already been discussed earlier (Chapter 6.1). Amongst the studied assemblages there were a number of particular deposits which did provide possible evidence of particular processing activities, or for the storage or import of fish.

Articulated segments of small fish have been noted at the early 5th millennium BC site at H3 in Kuwait (Chapter 5.2.1), associated with one of the rooms at the settlement. These mostly came from Chondrichthyes, small jacks, and seabream. Although the remains may simply represent waste from butchered fresh fish, judging from their size, it is also possible that they may represent small dried fish. Two articulated abdominal vertebrae from tuna were also recorded. The fact that the remains were associated with apparent floor deposits within an internal room of the stone walled building identified at the site strengthens the argument for such a case.

At the 6-5th millennium BC site at Dosariyah, a number of tuna vertebrae were recovered from a floor in trench 5, as well as from layer 3 sealed below it (Chapter 5.2.2.3). They were mostly abdominal and anterior caudal vertebrae. These floor deposits also included two cranial elements from kawakawa/little eastern tuna (*Euthynnus affinis*) from individuals sized between 80-90cm. The fact that both cranial and vertebral elements are present suggests that whole fish in some cases may have been brought to the site.

At the early 5th millennium BC site at Dalma, the majority of the grouper (*Serranidae*) bones came from cranial elements (Chapter 5.2.3.2.). There was also a disproportionate number of abdominal compared to cervical vertebrae. Whilst this may be explained by differential preservation (abdominal vertebrae are harder and more compact), it may indicate that grouper heads were being regularly removed, the remainder of the fish being consumed or disposed of elsewhere. As no chops or cut marks were observed to any of the cranial elements or abdominal vertebrae, it may just be that cervical vertebrae are generally poorly preserved. Tuna tail vertebrae were also well represented, but again this may simply be an effect of differential preservation.

On Sir Bani Yas island mostly small fish appear to have been caught by the inhabitants of the 6-7th century Nestorian monastery and its associated buildings (Chapter 5.2.4.5). At one of the courtyard villas (site SBY7), the primary fills of two "kitchen cupboards" (Figure 87) both contained groups of bones from small groupers, emperors and seabream, all between ca 20-30cm (Chapter 5.2.4.3). These possibly may represent fish being stored for later use. At the monastery itself (site SBY9), the best preserved group of material came from a series of ashy layers associated with the kitchen in the NE wing of the monastery (Chapter 5.2.4.4). A rich variety of archaeological remains was excavated from these contexts. This particular group of material included sheep/goat/gazelle-sized limb bone fragments, turtle fragments, dugong rib fragments, and several Socotra cormorant bones. Crab chelae as well as marine mollusca (including deliberately broken examples of the gastropod *Hexaplex kuesterianus*) were also noted. The fish remains largely consisted of cranial elements from emperors and seabream. This included a group of emperor otoliths (Chapter 7.5). Other remains included largely cranial and abdominal elements from groupers, parrotfish pharyngeals, vertebrae from Chondrichthyes, small jacks and needlefish, and tuna abdominal and tail vertebrae. All this material appeared to represent a dump of processed food.

The Late Islamic assemblage from site BG12 on Balghelam island was highly specialised (Chapter 5.2.7). Clearly the site principally represented some sort of camp where the inhabitants had butchered and cooked marine turtles, and occasionally dugong. The fish remains at the site consisted almost entirely of sawfish and indeterminate Chondrichthyes vertebrae fragments. This perhaps indicates that they may have also been targeting sharks and rays for their fins. The small number of other fish taxa present were probably fish caught in the nearby local waters.

The possibility that fishing may have been carried out within the Umm al Qaiwain lagoon targeting particular spawning aggregations of fish like emperors has already been discussed (Chapter 7.2 and 7.9). Such activities may have been commonplace judging from the evidence emerging from a number of sites like Al Markh in Bahrain and Khor in Qatar. These sites may be linked with the preparation of quantities of dried fish which could be then transported or traded to the interior. Dried whole seabream are still sold today at the inland oasis of Al Ain in the fish suq (Iddison 1998: 6).

At the inland site of Mleiha in Sharjah emirate (Chapter 4.1.3.), fish bones were reported from both the remains of a 3rd-4th century AD fort, as well as from adjacent houses (Mashkour and van Neer 1999). The assemblage was dominated by the remains of tuna, in particular by kawakawa/little eastern tuna (*Euthynnus affinis*), with smaller amounts of longtail tuna (*Thunnus* sp.), seabream (*Rhabdosargus* sp), jacks (including *Carangoides* sp.), mullets (Mugilidae) and requiem shark (*Carcharhinidae*). Mleiha is located at least ca. 50km from the east coast and 80km from the west coasts of the UAE, so all these fish remains must represent deliberate imports to the site.

The diverse range of marine fish discovered at the Iron age site of Rafaq included requiem sharks, sawfish, groupers, jacks (*Scomberoides*), snappers, emperors, seabream, kawakawa/little eastern tuna (*Euthynnus affinis*) as well as tuna, *Thunnus* (Chapter 5.2.13). This site is located about 25 km from the eastern coast of the UAE in the Wadi al Qawr, which acts as a natural east-west corridor between the Madam Plain at its western end with the northern Batinah coast at its eastern end. Whilst fresh fish may have been transported to the site from the coast, as the distance represents about a day's journey (Carl Phillips, pers. comm.), it is also possible that the fish may have arrived at the site in dried form. The majority of the fish remains included vertebrae, only snappers and tuna (*Euthynnus*) being represented by a few cranial elements. Differential preservation may, however, explain this bias towards the preservation of largely vertebrae. Many of the tuna vertebrae were posterior caudal vertebrae which survive better than other anterior elements. Nevertheless it is interesting that tail vertebrae were carried so far inland. This may suggest that the more recently observed preparation methods used to process tuna, which leave all the vertebrae intact within the fish (section 8.1.), have a long tradition in the region. The diversity of the fish assemblage present at Rafaq suggests that the trade in fish from the coast to the interior was already well established by this time. Most scombrids occur on the east coast within the space of a couple of months each year. Surplus catch of these fish may have been preserved by drying and salting for storage, export and/or trade. Further confirmation of the existence of a connection between the inhabitants of Rafaq with coastal communities came from the crab remains recovered at the site (Chapter 6.7). These largely consisted of chelae from mangrove crabs (*Scylla*). Whilst a small number of these were observed amongst the Umm al-Qaiwain assemblage within the Gulf, it seems more likely that these originated from the east coast. Almost identical size material was recovered from Kalba.

Sites in certain regions may have used their strategic location to exploit the seasonal occurrence of pelagic scombrids (Chapter 7.2). The northern emirates and east coast lie adjacent to deeper waters making them ideal locations to maximize catches of such fish. It is worth noting that according to the modern fisheries data available within the Gulf, scombrids may only be available there in any great quantity during a relatively small part of the year (Chapter 3.6, 3.7.1 and 3.7.2). This marked highly seasonal occurrence of pelagic fish within the Gulf permits a much smaller window of opportunity for their capture. At the present day in the UAE this is exemplified by the practice of shipping many such fish from the northern emirates southwards, as well as principally from the east coast westwards, to the cities and markets in the lower Gulf like Dubai and Abu Dhabi. The extended fishing season on the east coast makes this an economically worthwhile practice. Kalba during the Iron age (and probably during even earlier periods) may have witnessed the early beginnings of such a trade as merchants and their camels set out west through the Wadi Al-Qawr with their dried fish products collected and manufactured on the east coast.

8.3. Discussion

The development of copper mining in the mountains of the Oman peninsula during the 3rd millennium BC would have opened up new connections between many regions in SE Arabia (Potts 1990a,b, 1997; Weeks 1999). It is presumed that the copper ingots and many other products were transported largely by animals such as mules, as it is believed that the camel was not yet domesticated by this time in Arabia (Hans-Peter Uerpmann, pers. comm.). One of the key factors in the subsequent expansion of trade during the Iron age may have been the domestication of the camel (Magee 2000). It is now clear from the biometric evidence at Tell Abraq that the camel did not become domesticated until the Iron age during period Iron II, ca. 1100-600 BC (Uerpmann 2000). Once the camel was used more intensively this opened up further possibilities and opportunities for trade. The advantage of the camel was that it allowed merchants to venture into more sandy areas where mules could not successfully pass. In later periods, hybrids may have even been developed to combine the speed of the dromedary with the strength of the bactrian to create the ideal cargo transporter (Hans-Peter Uerpmann, pers. comm.). It is evident that during the Iron age there was a massive expansion of settlement activities into new areas.

Although fish remains have not been discovered at any sites within the interior of the northern Oman peninsula pre-dating the Iron age assemblage from Rafaq, this may simply reflect the fact that bone assemblages are generally not well preserved at inland sites in the region (Uerpmann 1989). If other cargo like copper, pottery, softstone vessels, etc. were already being transported around during the 3rd millennium BC then it seems highly unlikely that fish would not also have been similarly been transported as food for the merchants, as well as potentially for barter and trade. The transport of tuna clearly may have taken place even during earlier periods than this, even as far as Mesopotamia, e.g. two vertebrae were found amongst the food offerings at Ur, excavated by Sir Leonard Woolley (Ellison et al. 1978).

8.4. Summary

Can ethnographic data relating to fisheries in the United Arab Emirates provide any useful analogues for understanding archaeological fish assemblages?

Traditional methods used for the processing of fish, and in particular dried fish, in the United Arab Emirates leave few traces which can be identified in the archaeological record. Small fish are often dried whole. Medium and large fish are usually slit ventrally leaving all the vertebrae intact within the fish. Skulls are usually split, and the only other bones damaged are some parts of the branchial and appendicular skeleton. As elements in the branchial and appendicular skeleton are in any case quite fragile, it is not clear if their absence represents signs of genuine processing activities or simply poor preservation.

What zooarchaeological evidence is there for fish processing in the past? Can dried fish be detected in the archaeological record? Is there any evidence for the import/export (?trade) of fish products?

At the 6-5th millennium BC site at Dosariyah, a number of tuna vertebrae were recovered from a floor surface in trench 5, as well as from layer 3 sealed below it (Chapter 5.2.2.3). Cranial elements were also noted suggesting that whole fish in some cases may have been brought to the site. Articulated segments of small Chondrichthyes, jacks and seabream have been noted at the early 5th millennium BC site at H3 in Kuwait (Chapter 5.2.1), associated with one of the rooms at the settlement. At the early 5th millennium BC site at Dalma, the majority of the grouper (*Serranidae*) bones came from cranial elements (Chapter 5.2.3.2.). There was also a disproportionate number of abdominal compared to cervical vertebrae. Tuna tail vertebrae were also well represented. Although this may indicate that grouper heads and tuna tails were frequently removed, preservational biases may also account for this patterning. Fishing in shallow lagoon areas was clearly still of some importance to target fish like emperors (Chapters 5.2.8.1. and 7.9). This may have been carried out in conjunction with preparing quantities of dried fish. Small groupers, emperors and seabream were found in the primary fills of two "kitchen cupboards" at site SBY7, one of the Nestorian courtyard villas on Sir Bani Yas island (Chapter 5.2.4.3). These may represent fish being stored for later use. At the monastery on the same island (site SBY9), a typical kitchen waste deposit was identified (Chapter 5.2.4.4). A specialised "fishermens camp" was identified on Balghelam island, near Abu Dhabi, where turtles and Chondrichthyes were processed (Chapter 5.2.7). Iron age Rafaq (Chapter 5.2.13) and 3rd-4th century AD Mleiha (Chapter 4.1.3), both of which were located within the interior, had characteristic assemblages dominated by tuna, and other smaller inshore taxa. These all represented fish imported from the coast. Chelae from mangrove crabs (*Scylla*) were also identified at Rafaq (Chapters 5.2.13 and 6.7), suggesting close contacts with communities living adjacent to coastal mangrove areas, such as those still located near to Kalba on the east coast. Sites in certain areas may have used their strategic location to exploit the seasonal occurrence of pelagic fish (Chapter 7.3), and thus become a focus for establishing trade into the interior. The Wadi Al-Qawr may have acted as a natural east-west trade corridor between the east and west coasts of the northern Oman peninsula.

The following chapter will summarise the overall conclusions of this study.

CHAPTER 9.

CONCLUSIONS

The question whether ecological factors or social behaviour were the determining factors in formulating marine exploitation strategies is a complex one. Cultural adaptation to the marine environment was also obviously of some significance (e.g. Cleland 1982; Schalk 1977). It seems likely though that fishing strategies were largely defined by the integration of technology, behaviour and environment (Kirch and Dye 1979: 55). Various social factors such as trade and religion have also influenced prehistoric and particularly historic fishing strategies in some regions (Barrett 1995; Colley 1983). The climate and environment of the Arabian Gulf and Gulf of Oman clearly may have significantly influenced past human behaviour. Factors like mobility and scheduling the exploitation of marine resources would have been important subsistence strategies in this region.

Returning to the research objectives defined in Chapter 1:

9.1. Chronology

It is now clear that chronological factors do not necessarily play a major role in the structuring of fish bone assemblages within the Arabian Gulf and Gulf of Oman. It appears that broad environmental and ecological trends largely influence the composition of regional ichthyofaunas (section 9.2).

The previous model of fishing during the 5th-4th millennium BC within the Arabian Gulf, as portrayed by the assemblages from Al Markh (von den Driesch and Manhart 2000), Khor and Shagra (Desse 1988), and Site 69 at Umm al Qawain (Uerpmann and Uerpmann 1996), now has to be re-evaluated in the light of the findings from site H3 in Kuwait, Dosariyah and Dalma. The fish remains identified at these sites, and particularly at Dalma island in the southern Gulf, confirm that as early as 7000 years ago some coastal communities were capable of exploiting a broad range of marine resources, which included shallow water, reef and open water species. In particular, fishing for tuna and mackerel may have concentrated in some of the deeper waters adjacent to Dalma, where they were more readily available. Although tuna are generally caught in deeper offshore waters, at certain times of year they may come quite close to shore presenting an opportunity for the coastal inhabitants to exploit them. It has been reported that modern fishermen have long taken advantage of the tendency of tunas to aggregate around islands and over seamounts (Alverson 1963). The availability of more food in the vicinity of the islands than the surrounding seas has been suggested as a possible explanation for this phenomenon. Pelagic fish similarly gather seasonally near certain locations on the Omani coast, e.g. at Ra's al-Hadd and Ra's al-Jins (Cartwright 1994, 1998; Cleuziou and Tosi 2000).

Whilst fishing in shallow sandy waters and lagoons was clearly still important (e.g. at H3 in Kuwait and sites UAQ1+2 at Umm al-Qaiwain), it is clear that our previous impression of fishing during the 5^{th}-4^{th} millennium BC was largely coloured by the particular location of those already studied sites. The neolithic populations of the Gulf were clearly most capable fishermen. Excavations at the Dalma site demonstrate a picture of a much more settled way of life than the conventional hypotheses and models, which suggest that wandering fishing bedouin only made ephemeral trips to the coastline. It is surely no coincidence that tuna are only present within the Gulf in some quantities at sites like H3 in Kuwait, Dosariyah and Dalma, where house structures have all been identified (Carter et al. 1999; Masry 1974, 1997; Beech 2000; Beech and Elders 1999).

It is perhaps not surprising that that the communities within the Gulf were also exploiting tuna like their broadly contemporary counterparts on the Omani coast (Biagi et al. 1984). What we can only speculate about is what methods they used to capture them. No shell fish hooks have been so far published from the Gulf but this may be partly a question of visibility, and the relative intensity of research and excavations on the Omani coast. Perhaps it is just a question of time before similar finds are made like those described in Chapter 4.2.2. Most excavations on these early period sites are quite small trenches, so such material could easily have been missed. The main tuna species found in the Gulf, *Euthynnus affinis* and *Thunnus*, are both medium-sized fish which are caught by gillnets and surface trolling (*E.affinis*) and on longlines and purse seines (*Thunnus* spp.) at the present day (Carpenter et al. 1997: 224).

Why were tuna so important? Tuna are extremely fast growing fish, a 3 year old adolescent is already over a metre in length and weighs close to 45kg (Crockford 1994: 165). This would have made them attractive targets for accumulating large quantities of food, as well as making them suitable items for drying for storage (for the lean part of the year) or more importantly for trade.

The principal contrast which is drawn out by this analysis are sites which have assemblages dominated by shallow water and reef species, sites with marked quantities of Chondrichthyes and sites with higher numbers of pelagic fishes, particularly tuna and mackerel as well as large jacks. Assemblages in much of the northern, western and southern Gulf consisted of principally shallow water and reef species (with the exception of Dosariyah and Dalma). Chondrichthyes were frequent at two sites on the Abu Dhabi coastline, which may represent specific cultural activities or episodes (the diet of the Nestorian Christian community on Sir Bani Yas, and the Late Islamic turtle/shark processing site on Balghelam island). Sites on the Iranian Gulf coast, in the northern Emirates (with the exception of Umm al-Qaiwain), as well as those on the east (Gulf of Oman coast) coast, were characterised by higher numbers of pelagic fish, particularly tuna, mackerel and large jacks/trevallies. These data mirror to a great extent the present day composition in the modern fisheries data for these regions (Chapter 3).

Modern fisheries data demonstrate that although many types of fish like Chondrichthyes, jacks/trevallies, groupers, emperors and seabream were available throughout the Arabian Gulf and Gulf of Oman, large pelagic species such as tuna and Spanish mackerel were much more concentrated in their distribution. The importance of these species to the early communities of SE Arabia is demonstrated by the inclusion of tuna bones in one of the graves at the Umm al-Qaiwain cemetery. Tuna bones were also noted in the 3rd millennium BC Umm an-Nar tomb (UNAR2) at Ras al-Khaimah in the northern Emirates (Blau and Beech 1999). Future isotopic research on teeth and bones from some of the human skeletons within these tombs, as well as more importantly from the large contemporary cemetery at Al-Buhais 18, might help to partly resolve the question of whether distinctive separate groups of pastoralists and fishermen already existed in the early 5th millennium BC. However, poor preservation of material may partly preclude such an analysis, and in any case it seems likely that the mobility of the population would have allowed them a mixed diet.

9.3. Transhumance and Seasonality

There is an assumption in many current models relating to the inhabitants of SE Arabia that a transhumant pattern of occupation along the coasts in the winter was practiced, the people subsequently moving to their residences in the interior during the summer months (Potts 1997; Uerpmann and Uerpmann). Modern fisheries data from the Arabian Gulf suggests that although the winter months were a good time to catch certain pelagic species, like tuna and mackerel, the optimal time for many shallow water and reef species was between the late spring to early summer months. This time of year coincides with spawning aggregations of many of the major species represented at the archaeological sites (Abu-Hakima 1987; Hussain and Abdullah 1977; Sanders et al. 1984; Sheppard et al. 1992: 265).

There appeared to be some regional variation in the occurrence of scombrid remains. They represented a high proportion of all identified remains on the Iranian Gulf coast, as well as at the various sites located in the northern Emirates and on the east Gulf of Oman coast. Dalma island stands out amongst the sites located in the southern Gulf, having a higher proportion of scombrids. This suggests that at least some fishing may have been carried out during the cooler winter months. If fishing in the Gulf was mainly carried out during the optimal season between the late spring to early summer months, when many of the reef and shallow water species could be targeted, this may explain the low numbers of pelagic fish like tuna and mackerel in some assemblages. The targeting of spawning aggregations of fish like groupers, emperors and seabream may have coincided with the exploitation of other marine resources, such as the harvesting of pearls. A pilot study on archaeological otoliths from Sir Bani Yas island and Umm al-Qaiwain reveals that clear increments are preserved. If one accepts that the main annuli visible on the otoliths are annual, and that the hyaline band forms predominantly during the cooler winter months, then the majority of the fish were from young immature individuals and were caught between the spring/summer to early autumn months. Further modern work is urgently required to validate the precise timing and formation of opaque and hyaline zones, as well as the growth rate cycles of emperors in this region.

9.4. Fish processing, storage and trade

The name of the "ichthyophagi" carried far and wide in the ancient world, and this may have been partly due to the legendary abundance of fish in this region, as well as the regular export of dried fish over quite significant distances. Could the 7000 year old village on Dalma represent one of the earliest fish processing centres in SE Arabia? Certainly the inhabitants received imported pottery and beads from southern Mesopotamia, and surely they must have bartered or traded something in return. This may have been dates (Beech and Shepherd, forthcoming), pearls, or even fish, all of which are mentioned in early Mesopotamian texts. It is worth pointing out that an important discovery amongst the food offerings from Ur excavated by Sir Leonard Woolley were two tuna vertebrae with a maximum diameter of 28 and 33 mm (Ellison et al. 1978: 174, fig.4). These resemble the genus *Thunnus*, and may represent imports to the site from the Arabian Gulf (although the Mediterranean is also a possibility). Large Kassite copper fish hooks were also found at Ur which were of a size which could have been used to catch such fish (Woolley 1965).

The earliest evidence for the transportation of fish into the interior of the northern Oman peninsula can now be seen to date to the Iron age, at the site of Rafaq. Tuna was one of a number of taxa imported to the site. Whether it is just a coincidence that this coincides with the domestication of the camel remains unclear. During the Iron age there was certainly a great expansion of settlement into the interior of SE Arabia (Magee 1996a,b). However, it seems probable that marine resources would have been traded in earlier periods into the interior of SE Arabia and that it is simply a question of the poor preservation of material on most earlier sites located within the interior of Eastern Arabia (Uerpmann 1989).

9.5. Future Research Goals

Further work on other bioarchaeological remains from sites in the region, such as undertaking seasonality studies on the major species of marine mollusca exploited, will go some way towards providing a more comprehensive framework for understanding the regional exploitation of marine resources. If we are to effectively deal with the modelling of ancient fish exploitation in the Arabian Gulf and Gulf of Oman, then this can only be done by adopting such a regional perspective, and by incorporating other artefactual, historical, ecological and fisheries data into the equation.

The question of the differential preservation of fish taxa, and even particular elements from some taxa, remains a key unresolved problem. Further experimental work should be carried out to investigate the density and survival rates of the various skeletal elements of the major species represented on archaeological sites in the region. As there are a huge number of potential families and species existing in this area, this can only be done in collaboration with a number of specialists working with similar faunas in sub-tropical and tropical regions.

Further studies are urgently required to tackle the question of seasonality. Few detailed studies have been carried out on the modern fish of the region, let alone concerning archaeological remains. There clearly could be some interesting cross-fertilisation of ideas and exchange of data between modern fisheries biologists and ichthyo-zooarchaeologists working in SE Arabia. However, resolving problems like the cross-checking and validation of annuli on otoliths of the major economic species can only be done if a number of researchers cooperate in a long-term study.

9.6. Concluding statements

The "land of the ichthyophagi" could almost be called the "land of the regional ichthyophagi". Analysis of modern fisheries data as well as archaeological fish bone assemblages from the Gulf and Gulf of Oman suggest that certain resources may have been more readily available in particular areas. Some of these differences between sites may simply be due to variation in recovery methods, preservation, or other cultural factors. This is certainly the case for many of the smaller fish species. The eastern side of the Gulf, as well as the northern and eastern shores of the Oman peninsula in particular seem to have provided a broader range of potential taxa which could be exploited. This was particularly the case for larger pelagic fish like tuna and mackerel, as well as some of the larger species of jacks and trevallies.

The populations inhabiting southeastern Arabia clearly exploited the natural features of the land to help secure their existence. Ovicaprid pastoralism supplemented by other activities such as fishing, trading dried fish and salt, and agriculture in the oasis areas would have broadened their economic base and given more security to the inhabitants of this region. This particular way of life continued pretty much up until the pre-oil era (Cordes and Scholz 1980).

There appear to be few differences in the overall composition of ancient fish faunas compared with their modern counterparts. This apparent "equilibrium" may reflect a number of factors such as the fact that the Arabian Gulf is a comparatively young sea, and that up until very recently there have been very low levels of exploitation by the fisheries industry. However, this situation has changed during the last twenty years as the marine resources have been increasingly put under pressure. One of the well observed effects of over-fishing is reduction in the size of top predator species like groupers (*Serranidae*). It is noticeable that during the last seven years on Dalma island in the southern Gulf, the average size of groupers has apparently diminished (personal observation). Most of the groupers currently sold on Dalma during the months of April-May are only about 50-60cm total fork length, as opposed to some of the very large individuals of up to 90cm witnessed during the early 5th millennium BC. Whether these changes are entirely due to overfishing or a combination of other factors is unclear.

In 1998 more than 75% of the corals in the entire Indian Ocean died following a warming of surface seawater (Sheppard 2000). This appeared to be part of a general overall warming in the world. In some areas, including large parts of the Arabian Gulf, mortality over vast areas was greater than 95%. As some of these corals were several hundred years old it seems likely that this is a rare event. A direct result of this is that many dead coral reefs are now carpeted with algae. In the southern Arabian Gulf along the coastline of the United Arab Emirates, this has directly affected the composition of fish assemblages in reef areas. There has been a notable increase in the presence of herbivorous algal grazing fishes (David George and David John, Natural History Museum, London - pers.comm.). Similarly, there has been an apparent decrease in the numbers of classical reef associated species. Collapses in reef fish have also been observed in the Chagos islands, and large increases in herbivorous fishes have been noted in the Seychelles (Sheppard 2000). It is not clear whether these are just short term changes or if they will have a longer term significance for the composition of the Gulf fauna. Such events, whilst they may not be visible in the archaeological record if they prove to be short term, do stress the urgent need for longterm underwater monitoring and surveys to be carried out. As a number of marine biologists working in the region have pointed out, it is only by understanding the historical development of regional patterns and processes within the marine environment will effective protected areas be designated, so that the marine resources of the Gulf can be protected for future generations.

BIBLIOGRAPHY

Abe, T. and D. Pathansali. (1974). Lethrinidae. In: W. Fischer and P.J.P. Whitehead (eds.) FAO species identification sheets for fishery purposes. Eastern Indian Ocean (Fishing Area 57) and Western Central Pacific (Fishing Area 71). Volume 2. FAO, Rome.

Abu-Hakima, R. (1987). Aspects of the reproductive biology of the grouper, Epinephelus tauvina (Forskål), in Kuwaiti waters. Journal of Fisheries Biology 30: 213-222.

Acheson, J.M. (1981). Anthropology of Fishing. Annual review of Anthropology 10: 275-315.

Akazawa, T. (1969). Body size composition of the fish from the Jomon Shellmounds in Japan and the implications in the studies of fishing activities of the Jomon Shellmound People. Journal of the Archaeological Society of Nippon 77: 154-178.

Al-Baharna, W.S. (1986). Fishes of Bahrain. Bahrain: Directorate of Fisheries, Ministry of Commerce and Agriculture.

Aldonov, V.K. and A.D. Druzhinin. (1979). Some data on scavengers (Family Lethrinidae) from the Gulf of Aden region. Journal of Ichthyology 18: 527-535.

Al-Ghais, S.M. (1995). Heavy metal concentrations in the tissue of *Sparus sarba* (Forsskål, 1775) from the United Arab Emirates. Bulletin of Environvironmental Contamination and Toxicology 55: 581-587.

Al-Ghais, S. and R.T. Cooper. (1997). Brachyura (Grapsidae, Ocypodidae, Portunidae, Xanthidae and Leucosiidae) of Umm al Quwain mangal, United Arab Emirates. Tropical Zoology 9 (2): 409-430.

Ali, R.M. and T. Cherian. (1983a). Hydrographical conditions of the nearshore waters of the United Arab Emirates during 1981. Department of Fisheries, Ministry of Agriculture and Fisheries. Annual Report - Technical Report 6.

Ali, R.M. and T. Cherian. (1983b). Environmental conditions of the coastal waters of the United Arab Emirates during 1982. Department of Fisheries, Ministry of Agriculture and Fisheries, United Arab Emirates. Annual Report - Technical Report 9.

Ali, R.M. and P.J. Thomas. (1979). Fish landing survey in Khorfakkan, November 1976 to October 1977. Department of Fisheries, Ministry of Agriculture and Fisheries, United Arab Emirates. Annual Report - Technical Report 3.

Ali, R.M., P.J. Thomas, and S.S. Marji. (1980). Fish landing survey in Khorfakkan, May 1978 to April 1979, and in Kalba, June 1978 to May 1979. Department of Fisheries, Ministry of Agriculture and Fisheries, United Arab Emirates. Annual Report - Technical Report 5.

Ali, R.M., P.J. Thomas and S.S. Marji. (1984). Biology of some common fishes of U.A.E. Department of Fisheries, Ministry of Agriculture and Fisheries - Annual Report - Technical Report 10.

Al-Sedfy, H.M. (1982). Fishes of Qatar. Department of Fisheries. Ministry of Industy and Agriculture, Qatar.

Alverson, F.G. (1963). The food of yellowfin and skipjack tuna in the eastern Tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission 7: 293-396.

Anell, B. (1955). Contribution to the History of Fishing in the Southern Seas. Studia Ethnographica Upsaliensia IX.

Baddar, M.K. 1987. A preliminary study of the population dynamics of a sheiry, the starry pigface bream, "Lethrinus nebulosus". Kuwait Bull. Mar. Sci. 9: 215-220.

Badstöber, A. (2000). Die frügeschichtliche Meeresfauna von Siraf, einer mittelalterlichen Hafenstadt am Persischen Golf / Iran. Inaugural Dissertation zur Erlangung der tiermedizinischen Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität München.

Baillon, N. (1991). Otolithometrie en milieu tropical: application a trois especes du lagon de nouvelle-caledonie. ORSTOM, Inst. Fr. Rech. Sci. Dév. Coop., Trav. Doc. 113. 296 p.

Barrett, J.H. (1994). Bone weight and the intra-class comparison of fish taxa. In: W. Van Neer (ed.) (1994) Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium, 3-15.

Barrett, J.H. (1995). Few Know an Earl in Fishing-clothes - Fish Middens and the Economy of the Viking Age and Late Norse Earldoms of Orkney and Caithness, Northern Scotland. Dphil thesis. Department of Archaeology, University of Glasgow.

Barrett, J.H. (1997). Fish trade in Norse Orkney and Caithness: a zooarchaeological approach. Antiquity 71: 616-638.

Basson, P.W., J.E. Burchard Jr., J.T. Hardy A.R.G. Price. (1977). Biotopes of the Western Arabian Gulf: Marine Life and Environments of Saudi Arabia. Dhahran, Saudi Arabia: Aramco Department of Loss Prevention and Environmental Affairs.

Bädstober, A. (2000). Die frühgeschichtliche Meeresfauna von Siraf, einer mittelalterlichen Hafenstadt am Persischen Golf / Iran. Inaugural dissertation zur Erlangung der tiermedizinischen Doktorwürde der Tierärztlichen Fakultät der Ludwig-Maximilians-Universität, München.

Beckingham, C.F. (1994). Ibn Battutah, The Travels of Ibn Battutah, AD 1325-1354, vol. IV. Hakluyt Society, London.

Beckman, D.W. and C.A. Wilson. (1995). Seasonal timing of opaque zone formation in fish otoliths. In: D.H. Secor, J.M. Dean and S.E. Campana (eds.), Recent Developments in Fish Otolith Research. Belle W. Baruch Library in Marine Science, University of South Carolina Press, 27-43.

Beech, M. (1998). Comments on two vertebrate samples from early Islamic Jazirat al-Hulaylah (5th-9th c. AD) and Islamic Julfar (mid-14th - 16th c. AD), United Arab Emirates. Bulletin of Archaeology, University of Kanazawa 24: 197-203.

Beech, M. (1999). A new species of triggerfish recorded for the Arabian Gulf. Tribulus 9.1: 18-20.

Beech, M. (2000). Preliminary report on the faunal remains from an 'Ubaid settlement on Dalma island, United Arab Emirates. In: M. Mashkour, A.M. Choyke, H. Buitenhuis and F. Poplin (eds.), Archaeozoology of the Near East IV: Volume B - Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas. ARC Publicatie 32. Groningen, Netherlands, 68-78.

Beech, M. (forthcoming). The animal bones from Kush. In: D. Kennet, Exacavations at Kush, a Sasanian and Islamic tell in Ras al-Khaimah, United Arab Emirates.

Beech, M. and J. Elders. (1999). An 'Ubaid-related settlement on Dalma Island, United Arab Emirates. Bulletin of the Society for Arabian Studies 4: 17-21.

Beech, M. and A. Pipe. (1997). The Animal Bones. In: D. Kennet, Kush: a Sasanian and Islamic-period archaeological tell in Ras al-Khaimah (U.A.E.). Arabian Archaeology and Epigraphy 8: 284-302 (297-298).

Beech, M. and E. Shepherd (forthcoming). Archaeobotanical evidence for early date consumption on Dalma island, United Arab Emirates. Antiquity.

Belcher, W.R. (1991). Fish resources in anearly urban context at Harappa. In: R.H. Meadow (ed.), Harappa Excavations 1986-1990: a Multidisciplinary Approach to Third Millennium Urbanism. Prehistory Press, Madison, 107-120.

Belcher, W.R. (1994). Butchery practices and the ethnoarchaeology of South Asian fisherfolk. In: W. Van Neer (ed.) (1994) Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium, 169-176.

Belcher, W. (1998). Fish Exploitation of the Baluchistan and Indus Valley Traditions: An ethnoarchaeological approach to the study of fish remains. Dphil thesis. University of Wisconsin -Madison.

Benecke, N. (1988). Archaeozoologische Untersuchungen an Tierknochen aus der frümittelalterlichen Siedlung von Menzlin. Schwerin, Museum für Ur- und Frühgeschichte.

Bernier, P., R. Dalongeville, B. Dupuis and V.D. Medwecki. (1995). Holocene Shoreline Variations in the Persian Gulf: Example of the Umm Al-Qowayn Lagoon (UAE). Quaternary International 29/30: 95-103.

Best, E. (1929). Fishing Methods and devices of the Maori. Dominion Museum Bulletin 12. Wellington, New Zealand.

Biagi, P. and R. Nisbet (1989). Some aspects of the 1982-1985 excavations at the aceramic coastal settlement of RH5 at Qurm (Muscat – Sultanate of Oman). In: P.M. Costa and M.

Tosi (eds.), Oman Studies. Serie Orientale 63. Istituto Italiano Per Il Medio Ed Estremo Oriente. Roma, 31-46.

Biagi, P., W. Torke, M. Tosi and H.-P. Uerpmann (1984). Qurum: a case study of coastal archaeology in Oman. World Archaeology 16(1): 43-61.

Bibby, G. (1970). Looking for Dilmun. Pelican edition (1972), London.

Blau, S. (1998). Finally the Skeleton: An Analysis of Archaeological Human Skeletal Remains from the United Arab Emirates. Unpublished DPhil. thesis. University of Sydney.

Blau, S. and M. Beech. (1999). One woman and her dog: An Umm an-Nar example from the United Arab Emirates. Arabian Archaeology and Epigraphy 10: 34-42.

Blegvad, H. (1944). Danish Scientific Investigations in Iran. Part III. Fishes of the Iranian Gulf. Copenhagen: Einar Munksgaard.

Boer, B. (1997). An Introduction to the Climate of the United Arab Emirates. Journal of Arid Environments 35(1): 3-26.

Bosch, D., S.P. Dance, R.G. Moolenbeek and P.G. Oliver (1995). Seashells of Eastern Arabia (ed. S.P. Dance). Motivate, Dubai and London.

Bosworth, C.E. (1980). The Nomenclature of the Persian Gulf. In: J. Cottrell (ed.), The Persian Gulf States: A General Survey. Baltimore: Johns Hopkins University Press, 17-34.

Both, A. J. and C. D Buxton. (1997). The biology of the panga, Pterogymnus laniarius (Teleostei: Sparidae), on the Agulhas Bank, South Africa. Environmental Biology of Fishes 49: 207-226.

Boucharlat, R., R. Dalongeville, A. Hesse, and M. Millet. (1991). Occupation et environnement au 5e et 4e millénaire sur la côte de Sharjah-Umm al-Quaiwain (U.A.E.). Arabian Archaeology and Epigraphy 2(2): 93-106.

Boucharlat, R., E. Haerinck, O. Lecomte, D.T. Potts and K.G. Stevens, K.G. (1989). The European archaeological expedition to ed-Dur, Umm al-Qaiwayn (U.A.E.). An interim report on the 1987 and 1988 seasons. Mesopotamia 24: 5-11.

Boucharlat, R., E. Haerinck, C.S. Phillips and D.T. Potts. (1988). Archaeological reconnaissance at ed-Dur, Umm al-Qaiwain, Akkadica 58: 1-26.

Boucharlat, R., E. Haerinck, C.S. Phillips and D.T. Potts. (1991). Note on an Ubaid-pottery site in the Emirate of Umm al-Qaiwain. Arabian Archaeology and Epigraphy 2: 65-71.

Bökönyi, S. (1998). Animal husbandry, hunting and fishing in the Ras al-Junayz area: a basis for human subsistence. In: H. Buitenhuis, L. Bartosiewicz, and A.M. Choyke (eds.), Archaeozoology of the Near East III - Proceedings of the third international symposium on the archaeozoology of southwestern Asia and adjacent regions. ARC Publication 18. Groningen, Netherlands, 95-102.

Brock, R.E. (1982). A critique of the visual census method for assessing coral reef fish populations. Bulletin of Marine Science 32: 269-276.

Brothers, E.B. (1987). Methodological approaches to the examination of otoliths in ageing studies. In: R.C. Summerfelt and G.E. Hall (eds.), The Age and Growth of Fish. Iowa State University Press, 319-330.

Brunt, P.A. (ed./transl.) (1983). Arrian, Indica (Book VIII of Anabasis Alexandri: II, 306-446). London.

Bulloch, J. (1984). The Persian Gulf Unveiled. New York: Congdon and Weed.

Bullock, A.E. and A.K.G. Jones (1987). Dispersal of Fish Waste: A Modern Midden Experiment. Paper presented at the ICAZ Fish Remains Working Group Fourth Meeting, University of York, September 1987.

Burkholder, G. (1972). Ubaid sites and Pottery in Saudi Arabia. Archaeology 25: 264-269.

Burkholder, G. and M. Golding. (1971). Surface Survey of Al-Ubaid sites in Eastern Province, in H.Field (ed.), Contributions to the Anthropology of Saudi Arabia. Coconut Grove, Miami: Field Research Projects, 50-54.

Calvet, Y. and J. Gachet (1990). Failaka: Fouilles Françaises 1986-1988. Travaux de la Maison de l'Orient 18. Lyon.

Campana, S.E. and C.M. Jones. (1992). Analysis of Otolith Microstructure Data. In: D.K. Stevenson and S.E. Campana (eds.), Otolith Microstructure Examination and Analysis. Canadian Specialist Publication in Fisheries Aquatic Sciences 117. Ottowa, Canada, 73-100.

Cardi, B. de. (1973). Qatar Archaeological Report – Excavations 1973. Qatar National Museum and Oxford University Press.

Cardi, B. de. (1984). Survey in Ras al-Khaimah, UAE. In: R. Boucharlat and J.-F. Salles (eds.), Arabie orientale, Mesopotamie et Iran méridional de l'Age du Fer au début de la période islamique. Recherche sur les Civilisations Mémoire 37. Paris: ADPF, 201-216.

Cardi, B. de. (1985). Further Archaeological Survey in Ras al-Khaimah, UAE 1977. Oriens Antiquus 24: 164-240.

Cardi, B. de and B. Doe. (1983). Archaeological Survey in Southern Ras al-Khaimah, 1982 – Preliminary report. Proceedings of the Seminar for Arabian Studies 13: 31-35.

Carpenter, K.E. and G.R. Allen. (1989). FAO Species Catalogue. Vol. 9. Emperor fishes and large-eye breams of the world (family Lethrinidae). An annotated and illustrated catalogue of lethrinid species known to date. FAO Species Synop. No. 125(9).

Carpenter, K.E., F. Krupp, D.A. Jones and U. Zajonz, U. (1997). The Living Marine Resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. FAO Species Identification Field Guide for Fishery Purposes. Rome: FAO.

Carter, R. (1997). Defining the Late Bronze Age in Southeast Arabia: ceramic evolution and settlement during the second millennium BC. Unpublished DPhil. Thesis. Institute of Archaeology, University College, London.

Carter, R., H. Crawford, S. Mellalieu and D. Barrett. (1999). The Kuwait-British Archaeological Expedition to As-Sabiyah: Report on the first season's work. Iran 61: 43-58.

Cartwright, C. (1994). Preliminary results of the study of fish remains from a 3rd millenium B.C. site, HD1, at Ra's al-Hadd, Oman. In: W. Van Neer (ed.), Fish Exploitation in the Past. Tervuren: Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, 239-241.

Cartwright, C. (1998). Seasonal aspects of Bronze and Iron Age communities at Ra's al-Hadd, Oman. Environmental Archaeology 3: 97-102.

Casteel, R.W. (1976). Fish Remains in Archaeology and Palaeoenvironmental Studies. London, Academic Press.

Chaix, L. and J. Desse. (1994). L'os et sa mesure. Archéozoologie et archéometrie. Histoire & Mesure 9 (3/4): 339-363.

Chapman, R.W. (1971). Climatic Changes and the Evolution of Landforms in the Eastern Province of Saudi Arabia. Geological Society of America Bulletin 82: 2713-2728.

Charpentier, V. (1996). Archaeology of the Eryhthraean Sea: Craft specialization and resources optimization as part of the coastal economy on eastern coastlands of Oman during the 4th and 3rd millennium BC. In: G. Afanasev, S. Cleuziou, J.R. Lukacs and M. Tosi (eds.), The Prehistory of Asia and Oceania. 13th International Congress of Prehistoric and Protohistoric Sciences. Forli, Italy, 181-192.

Charpentier, V., M. Cremaschi and F. Demnard. (1997). Une campagne archéologique sur un site côtier du Ja'alan: Al-Haddah (BJD-1) et sa culture matérielle (Sultanat d'Oman). Proceedings of the Seminar for Arabian Studies 27: 99-111.

Charpentier, V. and S. Méry. (1997). Hameçons en nacre et limes en pierre d'Océanie et de l'Océan Indien: analyse d'une tendance. Journal de la Societé des Océanistes 2: 147-156.

Chiffings, T. (2000). Main Region 11: Arabian Seas. In: A Global Representative System of Marine Protected Areas - Volume 3. Central Indian Ocean, Arabian Seas, East Africa, and East Asian Seas. Great Barrier Reef Marine Park Authority, The World Bank and The World Conservation Union (IUCN) A Report to the World Bank Environment Department. Web: http://www.environment.gov.au/marine/marine_protected/nrsmpa/mpa/chap11.htm

Christensen, J.M. (1964). Burning of Otoliths, a Technique for Age Determination of Soles and Other Fish. Journal de Conseil 29: 73-81.

Clason, A.T. (1983). The Zoological Reference Collection of the Biologisch-Archaeologisch Instituut in Groningen. Palaeohistoria 25: 211-17.

Clason, A.T. and W. Prummel (1977). Collecting, Sieving and Archaeozoological Research. Journal of Archaeological Sciences 4: 171-75.

Cleland, C.E. (1982). The inland shore fishery of the northern Great Lakes: its development and importance in prehistory. American Antiquity 47: 761-784.

Cleuziou, S. (1980). Three seasons at Hili: Towards a chronology and culture history of the Oman peninsula in the 3rd millennium BC. Proceedings of the Seminar for Arabian Studies 10: 19-32.

Cleuziou, S. (1982). Hili and the beginnings of oasis life in eastern Arabia. Proceedings of the Seminar for Arabian Studies 12: 57-75.

Cleuziou, S. (1989). Excavations at Hili 8: A Preliminary report on the 4th to 7th campaigns. Archaeology in the United Arab Emirates 5: 61-89.

Cleuziou, S. and M. Tosi (eds.). (1986). The Joint Hadd Project. Summary report on the first season. December 1985. [Paris ERA 30 / Rome: IsMEO; circulated report].

Cleuziou, S. and M. Tosi (eds.). (1988). The Joint Hadd Project. Summary report on the second season. November 1986 – January 1987. Napoli: [Paris: ERA 30 / Rome: IsMEO; circulated report].

Cleuziou, S. and M. Tosi. (1989). The South-Eastern frontier of the Ancient Near East. In: K. Frifelt and P. Sørensen, (eds.), South Asian Archaeology 1985. London: Curzon Press, 15-47.

Cleuziou, S. and M. Tosi. (2000). Ra's al-Jinz and the Prehistoric Coastal Cultures of the Ja'alan. Journal of Oman Studies 11: 19-73.

Cleuziou, S., M. Tosi, and J. Reade (eds.). (1990). The Joint Hadd Project, Summary Report of the Third Season (1987-1988). [Paris: ERA 30 / Rome: IsMEO; circulated report].

Coles, S.L. and A.B. Tarr (1990). Reef fish assemblages in the Western Arabian Gulf: a geographically isolated population in an extreme environment. Bulletin of Marine Science 47 (3): 696-720.

Colley, S.M. (1983). Interpreting prehistoric fishing strategies: An Orkney case study. In: C. Grigson and J. Clutton-Brock (eds.), Animals and Archaeology: 2. Shell Middens, Fishes and Birds. British Archaeological Reports (Oxford) - International Series 183: 157-171.

Colley, S.M. (1990). The analysis and interpretation of archaeological fish remains.In: M.B. Schiffer (ed.), Archaeological Methods and Theory 2, Tucson, University of Arizona Press, 207-253.

Colley, S.M. and D.H.R. Spennemann (1987). Some methods of preparing fish skeletons in the Tropics. Journal of Field archaeology 14(1): 117-120.

Cordes, R. and F. Scholz, F. (1980). Bedouins, wealth, and change - A Study of Rural Development in the United Arab Emirates and the Sultanate of Oman. United Nations University. NRTS-13/UNUP-143. Web version: http://www.unu.edu/unupress/unupbooks/80143e/80143e00.htm

Costa, P.M. (1988). Fishing stations of the coast of Oman: A theme of ethno-archaeological research. Proceedings of the Seminar for Arabian Studies 18: 3-7.

Coutts, P.J.F. (1975). Marine fishing in archaeological perspective: techniques for determining fishing strategies. In: R.W.C. and G.I. Qirmby (eds.), Maritims Adaptations of the Pacific. The Hague, 265-306.

Crockford, S. (1994). New archaeological and ethnographic evidence of an extinct fishery for giant bluefin tuna (Thynnus thynnus orientalis) on the Pacific Northwest Coast of North America. In: W. Van Neer (ed.) (1994) Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium, 163-168.

Dalongeville, R. (1990). Présentation physique générales de l'isle de Failaka (Koxeit). In: Y. Calvet and J. Gachet (eds.), Failaka, Fouilles Française 1986-1988. TMP no. 18, 23-40. Maison de l'Orient, Lyon, 23-40.

Dalongeville, R. and P. Sanlaville, P. (1987). Confrontation des Datations Isotopiques avec Les Données Géomorphologiques et Archéologiques a Propos des Variations Relatives du Niveau Marin sur la Rive Arabe du Golfe Persique. In: O. Aurenche, J. Evin and F.Hourst, F. (eds.). Chronologies in the Near East: Relative Chronologies and Absolute Chronology 16,000-4,000 B.P. Oxford: British Archaeological Reports, International Series 379 (ii), 567-583.

Dalongeville, R., P. Bernier, B. Dupuis and V. Medwecki. (1993). Les Variations Recentes de la Ligne de Rivage dans le Golfe Persique: L'Example de la Lagune D'Umm al-Qowayn (Emirates Arabes Unis). Bulletin de l'Institut de Géologie du Bassin D'Aqitaines 53: 179-192.

Dayton, J. (1975). The Problem of Climatic Change in the Arabian Peninsula. Proceedings of the Seminar for Arabian Studies 5: 33-60.

Debelius, H. (1993). Indian Ocean tropical Fish Guide. Aquaprint, Neu Isenberg, Germany.

Dee, A.J. and R.L. Radtke (1989) Age and growth of the brick soldierfish, Myripristis amaena. Coral Reefs 8: 79-85.

Department of Fisheries. (1984). Study on mariculture environment of Umm al Quwain lagoon and the experimental rearing of shrimp, rabbitfish and mullet. Department of Fisheries, United arab Emirates, Ministry of Agriculture and Fisheries, Technical Report 8: 1-72.

Desse, J. (1988). Khor "P", Khor "F.B." et "Shagra". Les faunes. Le rôle de la pêche - Fish remains and micromammalian fauna from Khor and Shagra. Methodology and preliminary results. In: M.-L. Inizan (ed.), Prehistoire à Qatar. Mission Archéologique française à Qatar – vol 2. Paris, 157-165 and 225-226.

Desse, J. (1995). Archéo-icthyologie de Golfe arabique et de l'Océan Indien. In: H. Buitenhuis and H-P. Uerpmann (eds.), Archaeozoology of the Near East II – Proceedings of the second international symposium on the archaeozoology of southwestern Asia and adjacent areas. Backhuys, Leiden, 72-78.

Desse, J. and N. Desse-Berset. (1990). La faune: les Mammifères et les Poissons. Failaka, fouilles françaises 1986-1988. Travaux de la Maison de l'Orient 18. Diffusion de Boccard, Paris, 51-70.

Desse, J. and N. Desse-Berset (1996a). Archaeozoology of groupers (Epinephelinae) - Identification, osteometry and keys to interpretation. Archaeofauna 5: 121-127.

Desse, J. and N. Desse-Berset (1996b). On the boundaries of osteometry applied to fish. Archaeofauna 5: 171-179.

Desse, J. and N. Desse-Berset. (1996c). Les profils rachidiens globaux: Reconstitution de la taille des poissons et appréciation du nombre minimal d'individus à partir des pièces rachidiennes. Revue de Paléobiologie 8(1): 89-94.

Desse, J. and N. Desse-Berset. (2000). Julfar (Ras al-Khaimah, Emirats Arabes Unis), Ville Portuaire du Golfe Arabo-Persique (VIII-XVII siècles): exploitation des mammiferès et des poissons. In: M. Mashkour, A.M. Choyke, H. Buitenhuis and F. Poplin (eds.), Archaeozoology of the Near East IVB – Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas. ARC – Publicatie 32. Groningen, Netherlands, 79-93.

Desse-Berset, N. (1984). 2èmes Rencontres d'Archéo-Ichthyologie, CRA-CNRS, Valbonne. 2èmes Rencontres d'Archéo-Ichthyologie, Sophia Antipolis, Valbonne, France, C.N.R.S.

Desse-Berset, N. (1994). Haddrah et Gargour: Pêche traditionelle à Bahrain. Paris, CNRS Video - Audiovisuel.

Dipper, F. and T. Woodward. (1989). The Living Seas: Marine Life of the Southern Gulf. Motivate, Dubai.

Donaldson, W.J. (2000). Erthythraean Ichthyophagi: Arabian Fish-eaters Observed. New Arabian Studies 5: 7-32.

Dor, M. (1984). Checklist of fishes of the Red Sea. Israel Academy of Sciences and Humanities.

Downing, N. (1985). Coral reef communities in an extreme environment: The northwest Arabian Gulf. Proceedings of thr 5th International Coral Reef Congress, Tahiti. Vol. 6, 343-348.

Downing, N. (1987). A Study of the Corals and Coral Reef Fishes of Kuwait. Vol.III - The Coral Reef Fishes. 2 volumes (Part A. Text; Part B. Tables & Figures.) Report Project MB-42. Kuwait: Department of Mariculture and Fisheries, Kuwait Institute for Scientific Research.

Durante, S. and M. Tosi (1977). The aceramic shell middens of Ra's al-Hamra: Apreliminary note. Journal of Oman Studies 3: 137-162.

Dytham, C. (1999). Choosing and Using Statistics: A Biologists Guide. Blackwell Science, Oxford.

Ebisawa, A. (1990). Reproductive Biology of Lethrinus nebulosus (Pisces: Lethrinidae) Around the Okinawan Waters. Nippon Suisan Gakkaishi 56(2): 1941-1954.

Elders, J. and M. Beech. (1998). Oldest houses in UAE discovered. Emirates News, Tuesday, May 12, 1998. p.5.

Ellison, R., J. Renfrew, D. Brothwell and N. Seeley. (1978). Some food offerings from Ur, excavated by Sir. Leonard Woolley, and previousy unpublished. Journal of archaeological Science 5: 167-177.

Emery, K.O. (1956). Sediments and water of the Persian Gulf. Bulletin of the American Association of Petroleum Geology 40: 2354-2383.

Enghoff, I.B. (1994). Fishing in Denmark during the Ertebølle period. International Journal of Osteoarchaeology 4: 65-96.

Evans, J. and T.P. O'Connor. (1999). Environmental Archaeology: Principles and Methods. Sutton Publishing, Stroud.

Evans, G., V. Schmidt, P. Bush and H. Nelson. (1969). Stratigraphy and Geological History of the Sabkha, Abu Dhabi, Persian Gulf. Sedimentology 12: 145-159.

Ezzat, A.A., A.A. El-Sayed and N.M. El-Dossary. (1992). Growth of fish Lethrinus nebulosus from the Arabian Gulf waters off Dammam (Saudi Arabia). Indian Marine Sciences 21: 284-286.

Ferreira, B. and G. Russ. (1992). Age, growth and mortality of the inshore coral trout Plectropomus maculatus (Pisces: Serranidae) from the central Great Barrier Reef, Australia. Journal of Marine and Freshwater Research 43: 1301-1312.

Feulner, G. (1996). Geology of the United Arab Emirates. In: P.J. Vine (ed.), Natural Emirates – Wildlife and Environment of the United Arab Emirates. London: Trident Press, 21-40.

Fischer, W. and G. Bianchi (eds.). (1984). FAO Species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51). FAO, Rome, Vols. 1-5.

FishBase. (1998). FishBase 98 CD-ROM. ICLARM, Manila.

Flavin, K. and Shepherd, E. (1994). Fishing in the Gulf: Preliminary investigations at an Ubaid site, Dalma (U.A.E.). Proceedings of the Seminar for Arabian Studies 24: 115-134.

Fowler, A.J. (1990). Validation of annual growth increments in the otoliths of a small, tropical coral reef fish. Marine Ecology Progress Series 64: 25-38.

Fowler, A.J. (1995). Annulus formation in otoliths of coral reef fish: a review. In: D.H. Secor, J.M. Dean and S.E. Campana (eds.), recent developments in Fish Otolith research. Belle W. Baruch Institute for Marine Biology and Coastal research: University of South Carolina Press, 45-63.

Frifelt, K. (1991). The Island of Umm an-Nar. Volume 1, Third Millennium Graves. Jutland Archaeological Society Publications 26(1).

Frifelt, K. (1995). The Island of Umm an-Nar. Volume 2, The Third Millennium Settlement. Jutland Archaeological Society Publications 26(2).

Gee, J.H.R. and P.S. Giller. (1991). Contemporary community ecology and environmental archaeology. In: D.R. Harris and K.D. Thomas (eds.), Modelling ecological change. Institute of Archaeology, London, 1-12.

Gibb, H.A.R. (1958, 1962, 1971). Ibn Battutah, The Travels of Ibn Battutah, AD 1325-1354, translated with revisions and notes (from the Arabic text edited by C. Defremery and B.R. Sanguinetti) by H.A.R. Gibb (vols. I - 1958, II - 1962) and III (1971), and completed by C.F. Beckingham (vol. IV - 1994). Hakluyt Society, London.

Glennie, K.W., Pugh, J.M. and Goodall, T.M. (1993/4). Late Quaternary Arabian Desert Models of Permian Rotliegend Reservoirs. Exploration Bulletin 274: 1-19.

Goldman B. and F.H. Talbot. (1976). Aspects of the ecology of coral reef fishes. In: O.A. Jones and R. Endean (eds.), The Biology and Geology of Coral Reefs 3. Biology 2. Academic Press, New York, 125-154.

Grayson, D.K. (1979). On the quantification of vertebrate archaeofaunas. Advances in Archaeological Method and Theory 2: 199-237.

Grayson, D.K. (1984). Quantitative Zooarchaeology. New York: Academic Press.

Greenwood, P.H., D.E. Rosen, S.H. Weitzman and G.S. Myers (1966). Phyletic studies of teleostean fishes, with provisional classification of living forms. Bulletin of the American Museum of Natural History 131(4): 341-455.

Gubanov, E.P. and N.A. Shleib. (1980). Atlas of Hydrological and Fishery Data in the Territorial Waters of Kuwait. Kuwait, Fisheries Division, Ministry of Public Works.

Guinot, D. (1966). Les espèces comestibles de crabes dans l'Océan Indien occidental et la Mer Rouge. Mémoires Institute.Fonde.Afrique Noire 77: 353-390.

Haerinck, E. (1991). The rectangular Umm an-Nar period grave at Mowaihat (Emirate of Ajman (U.A.E.). Gentse Bijdragen tot de Kunstgeschiedensis en Oudheidkunde 29: 1-30.

Haerinck, E. and K.G. Stevens. (1989). The Belgian excavations. Mesopotamia 24: 45-52.

Hare, S. (1990). Sampling manual for data collectors aboard demersal trawlers. Special Report on Omani Marine Sciences Fisheries Center. 1 (1st revision), 99 pp.

Harmelin-Vivien, M.L., J.G. Harmelin, C. Chauvet, C. Duval, R. Galzin, P. Lejeune, G. Barnabe, F. Blanc, R. Chevalier, J. Duclerc and G. Lasserre. (1985). Evaluation visuelle des peuplements et populations de poissons: methods et problemes. Rev. Ecol. (Terre Vie) 40: 467-539.

Harrison, D.L. and P.J.J. Bates (1991). Mammals of Arabia. Harrison Zoological Museum, Sevenoaks.

Harter, G., S. Cleuziou, J.P. Laffont, J. Nockin and R. Toussaint. (1979). Emirat d'Abu Dhabi. Propositions pour Dalma (Sept.-Oct., 1979).

Heard-Bey, F. (1992). From Trucial States to United Arab Emirates. Longman, London.

Heasman, M.P. and D.R. Fielder. (1983). Laboratory spawning and mass rearing of the mangrove crab, *Scylla serrata* at different temperature and salinity levels. Marine Ecology Progress Series 139: 119-125.

Heinrich, D. (ed.) (1994). Archaeo-Icthyological Studies: Papers presented at the 6th meeting of the I.C.A.Z. Fish Remains Working Group, 3rd-7th September 1991, Archäologisches Landesmuseum, Schleswig/Germany. Offa 51.

Hellyer, P. (1990). The Natural History of Merawah Island: An Interim Report prepared for HH Sheikh Mohammed bin Zayed al Nahyan. June 1990. Privately published by the Emirates Natural History Group.

Hellyer, P. and M. Beech (forthcoming). Protected Areas and Cultural Heritage: An Abu Dhabi Case Study. In: Proceedings of the 1st International Symposium and Workshop on Arid Zone Environments: Research and Management Options for Protected Areas, Abu Dhabi, UAE (23-25th January 2000). ERWDA, Abu Dhabi.

Hellyer, P., J. Czastka, S. Aspinall and S. Garfi. (1995). An Introduction to the Archaeology and Natural History of Jazirat Balghelam, Abu Dhabi, UAE. Report submitted to H.H. Sheikh Surour bin Mohammed al Nahyan. Islands Joint Report No. 1 – ADIAS (Abu Dhabi Islands Archaeological Survey) and NARC (The National Avian Research Center), P.O.Box 45553, Abu Dhabi, U.A.E. - May 1995.

Hiryana, Y., T. Kusaka and Y. Hore. (1952). Size selection in fishing caused by size of hook and skill of angler. Japanese Journal of Ichthyology 2: 134-137.

Hoch, E. (1979). Reflections on prehistoric life at Umm an-Nar (Trucial Oman) based on faunal remains from the third millennium BC. In: M. Taddei (ed.), South Asian Archaeology. Papers from the Fourth International Conference of the association of South Asian archaeologists in Western Europe, held in the Istututo Universitario Orientale, Naples. Seminario di Studi Asiatici Series Minor 6: 589-638.

Hood, P.B. and R.A, Schlieder. (1992). Age, growth, and Reproduction of Gag, Mycteroperca microlepis (Pisces: Serranidae), in the eastern Gulf of Mexico. Bulletin of Marine Science 51(3): 337-352.

Hornby, R. J. (1997). A Survey of the Habitats, Invertebrate Fauna and Environmental Sensitivity of the Mainland Coast of the U.A.E., with Information on Status and Distribution of Crustaceans. Tribulus (Bulletin of the Emirates Natural History Group) 7(2): 11-17.

Hötzl, H., V. Maurin and J.G. Zötl. (1978). Geological History of the Al Hasa Area Since the Pliocene. In: S.S. Al-Sayari and J.G. Zötl (eds.), Quaternary Period in Saudi Arabia. Vienna: Springer-Verlag, 58-77.

Houde, E.D., S. Almatar, J.C. Leak and C.E. Dowd. (1986). Ichthyoplankton abundance and diversity in the western Arabian Gulf. Kuwait Bulletin of Marine Sciences 8: 107-393.

Hull, L.E. (1979). A provisional assessment of the fish stocks for the Gulf Coast of Saudi Arabia. Proceedings of the Saudi Biological Society 3: 303-317.

Huntingford, G.W.B. (transl. and ed.) (1980). The Periplus of the Erythraean Sea. The Hakluyt Society, London.

Hurum, H.J. (1976). A History of the Fish Hook. Adam and Charles Black, London.

Hussain, N.A. and M.A.S. Abdullah. (1977). The length-weight relationship, spawning season and food habits of six commercial fishes in Kuwaiti waters. Indian Journal of Fisheries 24 (1/2): 181-194.

Ibn Battutah. (1968). Rihlah: Ibn Battutah (Sams al-Din Abu 'Abdallah Muhammad b. 'Abdallah al-Lawati al-Tangi), Al-Rihlah, Beirut.

Iddison, P. (1998). A fish suq in the UAE desert. Privately published, Al Ain, UAE.

Jean, C.-F. (1931). Larsa d'après les textes cunéiformes. Paris.

Jennings, G. (1997a). The Sea and Freshwater Fishes of Arabia - The 1997 Classified Taxonomic Checklist.

Jennings, G. (1997b). The Sea and Freshwater fishes of Arabia, the Pocketbook: Volume 1 - An Identification Guide to the Unusual Species

Jennings, G. (1997c). The Sea and Freshwater fishes of Arabia, the Pocketbook: Volume 2 - An Identification Guide to the Typical Fish Species

Jennings, G. (1997d). The Sea and Freshwater fishes of Arabia, the Pocketbook: Volume 3 - An Identification Guide to the Sharks, Rays, Flatfishes, Cypriniformes,etc

Jennings, G. (1997e). The Sea and Freshwater fishes of Arabia: Addendum 1

Jennings, G. (1997f). Fishes of the World, Volume 3: The Sea and Freshwater Fishes of Arabia. CD (PC/Mac hybrid).

Johns, W.E., G.A. Jacobs, J.C. Kindle, S.P. Murray and M. Carron. (2000). Report of a Workshop on the "Arabian Marginal Seas and Gulfs". University of Miami RSMAS Technical Report 2000-01 - Report prepared by the Workshop Organizing Committee. Source: http://mpo.rsmas.miami.edu/~zantopp/AMSG-report.html

Johnson, A.G. (1983) Age and growth of Yellowtail Snapper from South Florida. Transactions of the American Fisheries Society 112: 173-177.

Jones, A.K.G. (1982). Bulk sieving and the recovery of fish remains from urban archaeological deposits. In: A.R.Hall and H.K.Kenward (eds.), Environmental Archaeology in the Urban Context. London: Council for British Archaeology, 79-85.

Jones, A.K.G. (1983). Some effects of the mammalian digestive system on fish bones. In: Desse-Berset, N. (1984). 2èmes Rencontres d'Archéo-Ichthyologie, CRA-CNRS, Valbonne. 2èmes Rencontres d'Archéo-Ichthyologie, Sophia Antipolis, Valbonne, France, C.N.R.S., 61-66.

Jones, A.K.G. (1984). Some effects of the mammalian digestive system on fish bones. In: N. Desse-Berset (ed.), 2èmes Rencontres d'Archéo-Ichthyologie, CRA-CNRS, Valbonne. 2èmes Rencontres d'Archéo-Ichthyologie, Sophia Antipolis, Valbonne, France, C.N.R.S., 61-65.

Jones, A.K.G. (1986). Fish bone survival in the digestive systems of the pig, dog and man: some experiments. In: D.C.Brinkhuizen and A.T.Clason (eds.), Fish and Archaeology. Oxford: British Archaeological Reports, International Series 294, 53-61.

Jones, A.K.G. (1987). Walking the Cod. Paper presented at the ICAZ Fish Remains Working Group Fourth Meeting, University of York, September 1987.

Jones, A.K.G. (1990). Experiments with fish bones and otoliths: Implications for the reconstruction of past diet and economy. In: D.E. Robinson (ed.), Experimentation and Reconstruction in Environmental Archaeology. Oxbow Books, Oxford, 143-146.

Jonsson, L. (1994). The estimation of fish size from bones and otoliths. Some methodological considerations and a simplified methods for use with limited comparative material. In: D. Heinrich (ed.) (1994) Archaeo-Icthyological Studies: Papers presented at the 6th meeting of the I.C.A.Z. Fish Remains Working Group, 3rd-7th September 1991, Archäologisches Landesmuseum, Schleswig/Germany. Offa 51, 379-383.

Juan-Muns, N. (1994). Fishing strategies in the Beagle Channel, Tierra del Fuego / Argentina: an ethnoarchaeological approach. In: D.Heinrich (ed) , Archaeo-Icthyological Studies: Papers presented at the 6th meeting of the I.C.A.Z. Fish Remains Working Group, 3rd-7th September 1991, Archäologisches Landesmuseum, Schleswig/Germany. Offa 51, 313-316.

Kapel, H. (1967). Atlas of the Stone Age cultures of Qatar. Jutland Archaeological Society Publications 6. University Press, Aarhus.

Kassler, P. (1973). The Structural and Geomorphic Evolution of the Persian Gulf. In: B.H. Purser (ed.), The Persian Gulf: Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Berlin: Springer-Verlag, 11-32.

Kempthorne, G.B. (1835). Notes made on a survey along the eastern shores of the Persian Gulf in 1828. Journal of the Royal Geographical Society 5: 263-85.

Kennet, D. (1997). Kush: a Sasanian and Islamic-period archaeological tell in Ras al-Khaimah (U.A.E.). Arabian Archaeology and Epigraphy 8: 284-302.

Kennet, D. (forthcoming). The Archaeology of the Sasanian and Islamic periods in Ras al-Khaimah, United Arab Emirates. Dphil thesis. School of Oriental and African Studies, University of London.

Kenward, H.K. (1978). The analysis of archaeological insect assemblages: a new approach. Council for British Archaeology, London.

Khalaf, K.T. (1961). The Marine and Freshwater Fishes of Iraq. University of Baghdad, Baghdad.

King, G.R.D. (1997). A Nestorian monastic settlement on the island of Sir Bani Yas, Abu Dhabi: a preliminary report. Bulletin of the School of Oriental and African Studies 60(2): 221-235.

King, G.R.D. (1998). Abu Dhabi Islands Archaeological Survey: Season I - An Archaeological Survey of Sir Bani Yas, Dalma and Marawah. London: Trident Press.

Kirch, P.V. and T.S. Dye (1979). Ethno-archaeology and the development of Polynesian fishing. Journal of the Polynesian Society 88: 53-76.

Klein, R.G. and K. Cruz-Uribe. (1984). The Analysis of Animal Bones from Archaeological Sites. Chicago: University of Chicago Press.

Kuronuma, K. (ed.) (1974). Arabian Gulf fishery-oceanography survey by the Umitaka-Maru, training research vessel, Tokyo University of Fisheries with collaboration of Kuwait Institute for Scientific Research, December 1968. Transactions of the Tokyo University Fisheries Department 1: 1-118.

Kuronuma, K. and Y. Abe. (1972). Fishes of Kuwait. Kuwait: Kuwait Institute for Scientific Research.

Kuronuma, K. and Y. Abe. (1986). Fishes of the Arabian Gulf. Kuwait: Kuwait Institute for Scientific Research.

Lambeck, K. (1996). Shoreline Reconstruction for the Persian Gulf Since the Last Glacial Maximum. Earth and Planetary Science Letters 142: 43-57.

Lancaster, W. (1988). Fishing and the Coastal Communities - Indigenous Economies: Decline or Renewal. In: The Scientific Results of The Royal Geographical Society's Oman Wahiba Sand Project 1985-1987. Journal of Oman Studies Special Report 3, 485-494.

Lancaster, W. and F. (1992). Tribe, community and the concept of access to resources: Territorial behaviour in southeast Ja'alan. In: M.J. Asimov and A. Rao (eds.), Mobility and territorality: Social and spatial boundaries among foragers, fishers, pastoralists and peripatetics. Berg Publishers, Providence/Oxford, 343-363.

Larsen, C.E. (1983). Life and Land Use on the Bahrain Islands: The Geoarchaeology of an Ancient Society. Chicago: The University of Chicago Press.

Latham, R. (transl.) (1958). The Travels of Marco Polo. Harmondsworth, England.

Leach, B.F. (1986). A method for the analysis of Pacific island fishbone assemblages and an associated database management system. Journal of Archaeological Science 13: 141-59.

Leach, F. (1999). Prehistoric Fishing in the Pacific Region and Human Influences on the Marine Environment. Paper presented at the ICAZ Fish Remains Working Group 1999, New York.

Leach, B.F. and A.S. Boocock. (1993). Prehistoric Fish Catches in New Zealand. Oxford: BAR International Series (Tempus Reperatum): 584.

Lecomte, O., R. Boucharlat and J.-M. Culas. (1989). Les fouilles françaises. Mesopotamia 24: 29-56.

Lehmann, C. (1991). Pottery Sherds – Sir Bani Yas. Unpublished report, 2-3rd May, 1991.

Longhurst, A.R. and D. Pauly. (1987). Ecology of Tropical Oceans. Academic Press, London.

Lou, D.C. (1992). Validation of annual growth bands in the otolith of tropical parrotfishes (Scarus schlegeli Bleeker). Journal of Fish Biology 41: 775- 790.

Lorimer, J.G. (1908-15). Gazetteer of the Persian Gulf, Oman and Central Arabia, (in 2 parts), Calcutta; reproduced by Farnborough and Shannon, 1970.

Løfgren, O. (ed.). (1951-54). Ibn al-Mugawir (1951-54). Mustabsir: Ibn al-Mugawir. Sifat Bilad al-Yaman wa-Makkah wa-ba'd al-Higaz, al-musammah Ta'rih al-Mustabsir (2 parts), Leiden.

MacArthur, R.H. and E.O. Wilson. (1967). The Theory of Island Biogeography. Princeton University Press, Princeton.

MacIvor, I. (1880-81). Notes on sea fishing in the Persian Gulf. Administration Report of the Persian Gulf Political Residency and Muscat Political Agency for 1880-81, Pt.III, Appendix A: 54-77, India Office Library Ref. R/15/6/480.

Magee, P. (1996a). Cultural change, variability and settlement in Southern Arabia. Unpublished Dphil thesis. University of Sydney.

Magee, P. (1996b). Excavations at Muweilah, Preliminary report on the First Two Seasons. Arabian Archaeology and Epigraphy 7: 195-213.

Magee, P. (2000). Recent research on the Iron age of south-east Arabia: excavations at Muweilah. Paper presented at the Historic Oman: Cultures, Contacts and Environment conference. British Museum, London. 17-19 July 2000.

Magurran, A.E. (1988). Ecological diversity and its measurement. Croom Helm, London.

Mahdi, N. (1962). Fishes of Iraq. Ministry of Education, Baghdad.

Mahdi, N. (1971). Additions to the Marine Fish Fauna of Iraq. Iraq Natural History Museum Publications 28: 1-43.

Marlowe, J. (1962). The Persian Gulf in the Twentieth Century. London: The Crusset Press.

Mashkour, M. and W. Van Neer (1999). Analyse des vestiges fauniques du fort et de la zone d'habitat de Mleiha (3e/4e siècles de notre ère). In: M. Mouton (ed.), Mleiha I - Environnement, stratégies de subsistance et artisanats. Maison de l'Orient méditerranéen 29, Lyon, 121-144.

Mason, D.L. and C.S. Manooch, III. (1985). Age and growth of mutton snapper along the east coast of Florida. Fisheries Research 3: 93-104.

Masry, A.H. (1974). Prehistory in northeastern Arabia: the problem of interregional interaction. Miami, Florida: Field Research Projects.

Masry, A.H. (1997). Prehistory in northeastern Arabia: the problem of interregional interaction. Kegan Paul International, London.

Mathews, C.P. and M. Samuel. (1983). The stock of "mixed fish" in Kuwait, the "bycatch" and their potential for exploitation. In: C.P. Mathews and A.R. Desai (eds.), Proceedings of the Third Shrimp and Finfish Management Workshop, Kuwait, 4-5 December 1982, 376-417.

McCain, J.C., A.B. Tarr, K.E. Carpenter and S.L. Coles. (1984). Marine ecology of Saudi Arabia - A survey of coral reefs and reef fishes in the Northern area, Arabian Gulf, Saudi Arabia. Fauna of Saudi Arabia 6: 102-126.

McClure, H.A. (1978). Ar Rub' Al Khali. In: S.S. Al-Sayari and J.G. Zötl (eds.), Quaternary Period in Saudi Arabia. Vienna: Springer-Verlag, 252-263.

Mellars, P.A. and M.R. Wilkinson. (1980). Fish otoliths as indicators of seasonality in prehistoric shell middens: The evidence from Oronsay (Inner Hebrides). Proceedings of the Prehistoric Society 46: 19-44.

Méry, S. and P. Marquis. (1998). First campaign of excavation at Khor Bani Bu Ali SWY-3, Sultanate of Oman. Proceedings of the Seminar for Arabian Studies 28: 215-228.

Meunier, F.J. and J. Desse (1994). Histological structure of hyperostotic cranial remains of Pomadasys hasta (*Osteichthyes, Perciformes, Haemulidae*) from archaeological sites of the Arabian Gulf and the Indian Ocean. In: W. Van Neer, W. (ed.) (1994). Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium, 47-53.

Miles, S.B. (1919). The Countries and Tribes of the Persian Gulf, (2 vols.), London. Republished in one volume with introduction by J.B. Kelly, London, 1966.

Millet, M. (1991). Comments on the lithic material from an 'Ubaid site in the Emirate of Ajman (U.A.E.). Arabian Archaeology and Epigraphy 2: 91-92.

Mohammed, H.A.M., J.M. Bishop and Y. Ye. (1998). Kuwait's Post Gulf-War Shrimp Fishery and Stock Status from 1991/92 Through 1995/96. Reviews in Fisheries Science 6 (3): 253-280.

Monks, G.G. and R. Johnston. (1993). Estimating season of death from growth increment data: a critical review. Archaeozoologia 5(2): 17-40.

Moon, J. and B. Irving. (1997). Faunal remains. In: H. Crawford, R. Killick and J. Moon (eds.), The Dilmun Temple at Saar: Bahrain and its archaeological inheritance. London and New York, London-Bahrain Archaeological Expedition: Saar Excavation reports 1, 81-83.

Morales, A.M.M. (1996). The evolution of the I.C.A.Z. Fish Remains Working Group (1981-1995). Archaeofauna 5: 13-20.

Morales, A.M.M., R.E. Izquierdo, S. Needs-Howarth and M.M. Garcia (eds.) (1996). Icthyoarchaeology: Fish and the Archaeological Record. Proceedings of the Eighth Meeting of the I.C.A.Z. Fish Remains Working Group, Madrid, 3-11 October 1995. Archaeofauna 5.

Morales-Nin, B. (1988). Age determination in a tropical fish, *Lethrinus nebulosus* (Forsskål, 1775) (*Teloeosteii: Lethrinidae*) by means of otolith interpretation. Inv. Pesq. 52(2): 237-244.

Morales-Nin, B. (1990). Age and growth of *Lutjanus kasmira* (Forskål) in Hawaiian waters. J. Fish Biol. 36: 191-203.

Morbin, A. (1995). United Arab Emirates. In: Middle East Review (20th edn.). London: Kegan Paul, 133-141.

Morgan, G.R. (1985). Status of the shrimp and fish resources of the Gulf. FAO Fisheries Circular 792. FIRM/C792, 1-49.

Mosseri-Marlio, M. (2000). Sea turtle and dolphn remains from Ra's al-Hadd, Oman. In: M. Mashkour, A.M. Choyke, H. Buitenhuis and F. Poplin (eds.), Archaeozoology of the Near East IVB – Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas. ARC – Publicatie 32. Groningen, Netherlands, 94-103.

Mosseri-Marlio, C. (in prep.). The mammals from Rafaq 2. In: C.S. Phillips, Excavations and Survey in the Wadi Al-Qawr.

Nellen, W. (1973). Kinds and abundances of fish larvae in the Arabian Sea and the Persian Gulf. In: The Biology of the Indian Ocean. Springer-Verlag, Berlin, 415-430.

Nicholson, R.A. (1996). Fish bone diagenesis in different soils. Archaeofauna 5: 79-91.

Norman, J.R. (1939). Fishes in The John Murray Expedition 1933-34, Scientific Reports, vol. 7: 1-116. British Museum (Natural History), London.

Nützel, W. (1975). The formation of the Arabian Gulf from 14000 BC. Sumer 31: 101-104.

O'Connor, T.P. (1989). Bones from the Anglo-Scandinavian levels at 16-22 Coppergate. The Archaeology of York 15/3. Council for British Archaeology, London.

Oliveira, R.F., J.L. Machado, J.M. Jordão, F.L. Burford, C. Latruffe and P.K. McGregor. (2000). Human exploitation of male fiddler crab claws: behavioural consequences and implications for conservation. Animal Conservation 3: 1-5.

Orton, C. (1980). Mathematics in Archaeology. Collins, London.

Panella, G. (1980). Growth Patterns in fish sagittae. In: D.C. Rhoads and R. A. Lutz (eds.), Skeletal Growth of Aquatic Organisms. Plenum, New York, 519-60.

Payne, S. (1975). Partial recovery and sample bias. In: A.T.Clason (ed.), Archaeozoological

Studies. Amsterdam: North Holland, 7-17.

Peck, M.C. (1986). The United Arab Emirates: A Venture in Unity. London: Croom Helm.

Pelly, L. (1863). Remarks on the tribes, trade and resources around the shore line of the Persian Gulf. Transactions of the Bombay Geographical Society 17: 32-112.

Pengelley, W.M. (1860). Remarks on a portion of the eastern coast of Arabia between Muscat and Sohar. Transactions of the Bombay Geographical Society 16: 30-39.

Perdikaris, S.P. (1998). From chiefly provisioning to state capital ventures: The transition from natural to market economy and the commercialization of cod fisheries in medieval arctic Norway. Dphil thesis. City University of New York, Graduate Faculty in Anthropology.

Phillips, C.S. (1997). Pattern of settlement in the Wadi al-Qawr. Proceedings of the Seminar for Arabian Studies 27: 205-218.

Phillips, C.S. (forthcoming). Prehistoric middens and a cemetery from the southern Arabian Gulf. In: M. Tosi, S. Cleuziou and J. Zarins (eds.), Arabia Antiqua.

Phillips, C.S. and T.J. Wilkinson (1979). Recently Discovered Shell Middens near Quriyat. Journal of Oman Studies 5: 107-110.

Pielou, E.C. (1975). Ecological Diversity. John Wiley, New York.

Plotnick, R.E., T. Baumiller and K.L. Wetmore. (1988). Fossilization potential of the Mud Crab, *Panopeus* (Brachyura: Xanthidae) and temporal variability in crustacean taphonomy. Palaeogeography, Palaeoclimatology and Palaeoecology 63: 27-43.

Postgate, N. (1992). Early Mesopotamia: Society and Economy at the Dawn of History. Routledge, London and New York.

Potts, D.T. (1989). The Danish excavations. Mesopotamia 24: 13-27.

Potts, D.T. (1990a). The Arabian Gulf in Antiquity: From Prehistory to the Fall of the Achaemenid Empire, Vol. I. Oxford: Clarendon Press.

Potts, D.T. (1990b). The Arabian Gulf in Antiquity: From Alexander the Great to the Coming of Islam, Vol. II. Oxford: Clarendon Press.

Potts, D.T. (1990c). A Prehistoric Mound in the Emirate of Umm al-Qaiwain, U.A.E.: Excavation at Tell Abraq in 1989. Copenhagen: Munksgaard.

Potts, D.T. (1993a). Four seasons of excavation at Tell Abraq. Proceedings of the Seminar for Arabian Studies 23: 117-126.

Potts, D.T. (1993b). Rethinking some aspects of trade in the Arabian Gulf. World Archaeology 24(3): 423-440.

Potts, D.T. (1997). Before the Emirates: An Archaeological and Historical Account of Developments in the Region c.5000 BC to 676 AD. In: E. Ghareeb and I. Al Abed (eds.), Perspectives on the United Arab Emirates. Trident Press, London, 36-73.

Potts, D.T. (2000). Ancient Magan – The Secrets of Tell Abraq. London: Trident Press.

Price, P.W. (1975). Insect Ecology. John Wiley, New York.

Prieur, A. and C. Guerin (1991). Découverte d'un site préhistorique d'abattage de dugongs à Umm al-Qaiwain (Emirats Arabes Unis). Arabian Archaeology and Epigraphy 2(2): 72-83.

Purser, B.H. (1973). The Persian Gulf: Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea. Berlin. Heidelberg, New York: Springer Verlag.

Radcliffe, W. (1926). Fishing from the Earliest Times. 2nd edition. John Murray, London.

Randall, J.E. (1986). Sharks of Arabia. Immel Publishing, London.

Randall, J.E., N. Downing, L.J. McCarthy, B.E. Stanaland and A.B. Tarr. (1994). Fifty-one New records of Fishes from the Arabian Gulf. Fauna of Saudi Arabia 14: 220-258.

Randall, J.E. (1995). Coastal Fishes of Oman. Bathurst, Australia: Crawford House Publishing.

Randall, J.E., G.R. Allen, and W.F. Smith-Vaniz. (1978). Illustrated Identification Guide to Commercial Fishes (of Arabian Gulf and Gulf of Oman). Food and Agriculture Organisation of the United Nations and Nations Development Programme, Rome.

Reefbase (1996). Reefbase CD-ROM. ICLARM-WCMC.

Regan, C.T. (1905). On fishes from the Persian Gulf, the Sea of Oman, and Karachi, collected by Mr. F.W. Townsend. Journal of the Bombay Natural History Society 16: 318-333.

Relyea, K. (1981). Inshore Fishes of the Arabian Gulf. George Allen and Unwin, London.

Reynolds, R.M. (1993). Physical oceanography of the Gulf, Strait of Hormuz, and the Gulf of Oman--Results from the Mt Mitchell expedition The 1991 Gulf War: Coastal and Marine Environmental Consequences. Marine Pollution Bulletin 27: 35-39.

Rice, M. (1994). The Archaeology of the Arabian Gulf c. 5000-323 BC. London: Routledge.

Richter, J. (1986). Experimental study of heat induced morphological changes in fish bone collagen. Journal of Archaeological Science 13: 477-81.

Ringrose, T.J. (1993). Bone counts and statistics: A Critique. Journal of Archaeological Science 20: 121-157.

Roberts, C.M. (1986). Aspects of Coral Reef Fish Community Structure in the Saudi Arabian Red Sea and on the Great Barrier Reef. D.Phil thesis, Department of Biology, University of York, UK.

Roberts, C.M., R.F.G. Ormond and A.R. Dawson Shepherd. (1988). The usefulness of butterflyfishes as environmental indicators on coral reefs. Proceedings of the 6th International Coral Reef Symposium, Townsville, 2: 331-336.

Russell, B.C., F.H. Talbot, F.R.V. Anderson and B. Goldman (1978). Collection and sampling of reef fishes. In: T. Stoddart and R.E. Johannes (eds.), Handbok of Coral Reef Research Methods. Paris, Unesco. pp.329-345.

Ryder, M.L. (1969). Remains of fishes and other aquatic animals. In: D.Brothwell and E.Higgs (eds.), Science in Archaeology, London: Thames and Hudson, 376-94.

Saggs, H.W.F. (1965). Everyday Life in Babylonia and Assyria. B.T. Batsford, London.

Sale, P.F. (1980). The ecology of fishes on coral reefs. Oceanogr. Marine Biology Annual Review 18: 367-421.

Sale, P.F. and W.A. Douglas (1981). Precision and accuracy of visual census techniques for fish assemblages. Environmental Biology of Fishes 6 (3/4): 333-339.

Salem, M. (2000). Age, growth, and mortality of shour, *Lethrinus nebulosus* from Ras Mohammed, northern Red Sea, Egypt. DPhil. Thesis, Department of Biology, University of York.

Salonen, A. (1970). Die Fisherei im Alten Mesopotamien - Nach Sumerisch-Akkadischen Quellen. Annales Academiae Scientarium Fennicae - Sarja-Ser. B - Nide-Tom.166.

Samuel, M., C.P. Mathews and A.S. Bawazeer. (1987). Age and validation of age from otoliths for warm water fishes from the Arabian Gulf. In: R.C. Summerfelt and G.E. Hall (eds.), The Age and Growth of Fish. Iowa State University Press, Ames, Iowa, 253-265.

Sanders, M.J. and G.R. Morgan. (1989). Review of the fisheries resources of the Red Sea and Gulf of Aden. FAO Fish. Tech. Rep. (304): 1-138.

Sanders, M.J., S.M. Kedidi and M.R. Hegazy. (1984). Stock assessment for the spangled emperor ("Lethrinus nebulosus") caught by small scale fishermen along the Egyptian Red Sea coast. Project for the Develpoment of Fisheries in the areas of the Red Sea and Gulf of Aden, FAO/UNDP RAB/83/023/01. Cairo.

Sanlaville, P. (1989). Considérations sur l'Évolution de la Basse Mésopotamie au Cour des Derniers Millénaires. Paléorient 15/2: 5-27.

Sanlaville, P. (1992). Changements Climatiques Dans la Péninsule Arabique Durant le Pléistocène Supérieur et l'Holocène. Paléorient 18/1: 5-26.

Sasaki, T. (1995). 1994 excavations at Jazirat al-Hulayla, Ras al-Khaimah. Bulletin of Archaeology - The University of Kanazawa 22: 1-74.

Sasaki, T. and H. Sasaki. (1998). 1997 excavations at Jazirat al-Hulayla, Ras al-Khaimah, U.A.E. Bulletin of Archaeology - The University of Kanazawa 24: 99-196.

Schalk, R.F. (1977). The Structure of an Anadromous Fish resource. In: L.R. Binford (ed.), For Theory Building in Archaeology. Academic Press, New York, 207-249.

Schäfer, W. (1972). Ecology and Palaeoecology of Marine Environments. Edinburgh: Oliver & Boyd.

Schoff, W.H. (transl. and ed.) (1912). The Periplus of the Erythraean Sea: travel and trade in the Indian Ocean by a merchant of the first century, London.

Shackley, M. (1981). Environmental Archaeology. London: George Allen and Unwin.

Shepherd, E., M. Beech, J. Elders and G.R.D. King. (forthcoming). Excavations at an early 5th millennium BC site on Dalma island, U.A.E. Abu Dhabi Islands Archaeological Survey, Abu Dhabi.

Sheppard, C. (1988). Similar trends, different causes: Responses of corals to stressed environments in Arabian seas. Proceedings of 6th International Coral Reef Symposium, Townsville, Australia, 3, 297-302.

Sheppard, C. (2000). The fate of reefs in the Indian Ocean region: consequences, costs and monitoring. Paper presented at the 2nd Arab International Conference and Exhibition on Environmental Biotechnology (Coastal Habitats), 8-12 April 2000, Abu Dhabi, U.A.E.

Sheppard, C., A. Price, and C. Roberts. (1992). Marine Ecology of the Arabian Region: Patterns and processes in extreme tropical environments. London: Academic Press.

Siebold, E. (1973). Biogenic sedimentation of the Persian Gulf. In: B. Zeitzschel (ed.). The Biology of the Indian Ocean. New York: Springer Verlag, 103-114.

Siddeek, M.S.M., M.M. Fouda and G.V. Hermosa, Jr. (1999). Demersal Fisheries of the Arabian Sea, the Gulf of Oman and the Arabian Gulf. Estuarine, Coastal and Shelf Science 49 (Supplement A): 87-97.

Sivasubramaniam, K. and M.A. Ibrahim. (1982). Common Fishes of Qatar. Doha, Qatar: Marine Sciences Department, University of Qatar.

Smale, M.J. and A.E. Punt. (1991). Age and growth of the red steenbras Petrus rupestris (Pisces: Sparidae) on the south-east coast of South Africa. South Africa Journal of Marine Science 10: 131-139.

Smith, G.B. and M.A. Saleh. (1987). Abundance and Bathymetric Distribution of Bahrain (Arabian Gulf) Reef Ichthyofaunas. Estuarine, Coastal and Shelf Science 24: 425-431.

Smith, G.B, M. Saleh and K. Sangoor. (1987). The Reef Ichthyofauna of Bahrain (Arabian Gulf) with Comments on its Zoogeographic Affinities. Arabian Gulf Journal of Scientific Research in Agriculture and Biological Sciences 5(1): 127-146.

Smith, G.H. (1978). Two prehistoric sites on Ras Abaruk, Site 4. In: B. de Cardi (ed.), Qatar Archaeological Report - Excavations 1973. Oxford, Oxford University Press, 80-106.

Smith-Vaniz, W.F., L.S. Kaufman and J. Glowacki. (1995). Species-specific patterns of hyperostosis in marine teleost fishes. Marine Biology 121: 573-580.

Stanger, G. (1994). Part II. Environmental Factors Affecting Early Settlement South of the Jabal Al-Akhdar, Oman. Iraq 61: 89-100.

Steensgard, N. (1973). Carracks, Caravans and Companies: The Structural Crisis in the European-Asian trade in the Early Seventeenth Century. Denmark: Student Literature.

Stevens, J.H. (1975). Some Effects of Irrigated Agriculture on Soil Characteristics in Ras al-Khaimah, Union of Arab Emirates. Arabian Studies 2: 148-166.

Stuiver M., P.J. Reimer, E. Bard, J.W. Beck, G.S. Burr, K.A. Hughen, B. Kromer, G. McCormac, J. van der Plicht and M. Spurk (1998). INTCAL98 Radiocarbon Age Calibration, 24000-0 cal BP - Radiocarbon 40(3) 1041-1083.

Taha, M.Y. (1975). Tarqibat al-Ba'that al-Athariyat al-'Iraqiyya ft mastantin al-darbhaniyya al-imarra Ras al-khayma, dawlat al-amirat al-arabiyyat al-mutahida. Sumer 31: 283-309.

Taubert, B.D. and Cobble, D.W. (1977). Daily rings in the otoliths of three species of Lepomis and Tilapia mossambica. Journal of the Fisheries Research Board of Canada 34: 332-340.

Tixier, J. (1977). Missions Archeologique Françaises à Qatar. Doha and Paris.

Toor, H.S. (1963). Studies on the systematics, biology and fishery of the fishes of the family *Lethrinidae* from Indian waters. Ph.D. thesis submitted to the Punjab University, Chandigarh, India.

Toor, H.S. (1968). Biology and fishery of the pig-face bream, *Lethrinus lentjan* (Lacépède) from Indian waters. III. Age and growth. Indian Journal of Fisheries 11(A)(2): 598-620.

Tosi, M. (1986). Early maritime cultures of the Arabian Gulf and the Indian Ocean. In: Sheikha H. Al-Khalifa and M. Rice (eds.), Bahrain through the Ages, the archaeology. K.P.I, 94-107.

Uerpmann, H-P. (1989). Problems of archaeo-zoological research in Eastern Arabia. In: P.M. Costa and M. Tosi (eds.), Oman Studies - Papers on the Archaeology and History of Oman 58. Istituto Italiano per il Medio Ed Estremo Oriente, 163-168.

Uerpmann, H-P. (2000). The camel in Arabia. Paper presented at the Historic Oman: Cultures, Contacts and Environment conference. British Museum, London. 17-19 July 2000.

Uerpmann, M. (1992). Structuring the Late Stone Age of Southeastern Arabia. Arabian Archaeology and Epigraphy 3: 65-109.

Uerpmann, M. and H-P. Uerpmann. (1994). Animal bone finds from Excavation 520 at Qala'at al-Bahrain. In: F. Hojlund and H.H. Andersen (eds.), Qala'at al-Bahrain. Vol 1. The Northern City Wall and the Islamic Fortress. Jutland Archaeological Society Publications 30 (1), Aarhus, 417-444.

Uerpmann, M. and H-P. Uerpmann. (1996). 'Ubaid pottery in the eastern Gulf - new evidence from Umm al-Qaiwain (U.A.E.). Arabian Archaeology and Epigraphy 7: 125-139.

Uerpmann, M. and H-P. Uerpmann (2000). Faunal remains of al-Buhais 18, an aceramic neolithic site in the Emirate of Sharjah (SE-Arabia) – Excavations 1995-1998. In: M. Mashkour, A.M. Choyke, H. Buitenhuis and F. Poplin (eds.), Archaeozoology of the Near East IVB – Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas. ARC – Publicatie 32. Groningen, Netherlands, 40-49.

Van Neer, W. (1992). Limits of incremental growth in seasonality studies: the example of the Clariid pectoral spines from the Byzantino-Islamic site of Apamea (Syria; sixth to seventh century A.D.). International Journal of Osteoarchaeology 3: 119-127.

Van Neer, W. (ed.) (1994). Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium.

Van Neer, W. and A. Gautier. (1993). Preliminary report on the faunal remains from the coastal site of Ed-Dur, 1st-4th century A.D., Umm Al-Quwain, United Arab Emirates. In: H. Buitenhuis and A.T. Clason (eds.), Archaeozoology of the Near East - Proceedings of the first international symposium on the archaeozoology of southwestern Asia and adjacent areas. Leiden: Universal Book Services / Dr. W.Backhuys, 110-118.

Van Neer, W. and M. Uerpmann. (1994). Fish remains from Excavation 520 at Qala'at al-Bahrain. In: F. Hojlund and H. Hellmuth-Andersen (eds.), Qala'at al-Bahrain: 1 - The Northern City Wall and the Islamic Fortress. Jutland Archaeological Society Publications, 445-454.

Velde, C. (1998). A new Umm al-Nar tomb at Shimal. National Museum of Ras al-Khaimah. Web: http://www.dur.ac.uk/~drk0dk/unar2.html

Vita-Finzi, C. (1978). Recent Alluvial History in the Catchment of the Arabo-Persian Gulf. In: W.C. Brice (ed.), The Environmental History of the Near and Middle East Since the Last Ice Age. London: Academic Press, 255-261.

Vogt, B. (1985). Zur Chronologie und Entwicklung der Gräber des Späten 4.-2. Jtsd.v.Chr. auf der Halbinsel Oman: Zusammenfassung, Analyse und Würdigung publizierte wie auch unveröffentlichter Grabungsergebnisse. PhD thesis. University of Göttingen.

Vogt, B. and Franke-Vogt, U. (eds.). (1987). Shimal 1985/6 – Excavations of the German Archaeological Mission in Ras al-Khaimah, UAE. A Preliminary Report. Berlin: Berliner Beiträge zum Vorderen Orient 8.

Vogt, B., W. Gockel, H. Hofbauer and A.A. Al-Haj. (1989). The coastal survey of the western province of Abu Dhabi, 1983. Archaeology in the United Arab Emirates 5: 49-60.

von den Driesch, A. (1994). Viehaltung, Jagd und Fischfang in der bronzezeitlichen Siedlung von Shimal bei Ras al-Khaimah/U.A.E. In: P. Calmeyer, K. Hecker, L. Jacob-Post, and C.B.F. Walker (eds.), Beiträge zur Altorientlischen Archäologie und Altertumskunde. Festschrift für Barthel Hrouda zum 65. Geburstag. Wiesbaden: Harrassowitz, 73-85.

von den Driesch, A. and H. Manhart. (2000). Fish bones from Al Markh, Bahrain. In: M.Mashkour, A.M. Choyke, H.Buitenhuis and F.Poplin (eds.), Archaeozoology of the Near

East IVB – Proceedings of the fourth international symposium on the archaeozoology of southwestern Asia and adjacent areas. ARC – Publicatie 32. Groningen, Netherlands, 50-67.

Walters, I. (1984). Gone to the dogs: A study of bone attrition at a central Australian campsite. Mankind 14: 389-400.

Wassef, E.A. (1991). Comparative growth studies on *Lethrinus lentjan*, Lacépède 1802 and *Lethrinus mahsena*, Forsskål 1775 (Pisces, Lethrinidae) in the Red Sea. Fisheries Research 11: 75-92.

Weeks, L. (1999). Lead isotope analyses from Tell Abraq, United Arab Emirates: new data regarding the 'tin problem' in Western Asia. Antiquity 73 (no. 279): 49-64.

Wellsted, J.R. (1837). Narrative of a journey into the interior of Oman. Journal of the Royal Geographical Society 7: 102-113.

Wellsted, J.R. (1838). Travels in Arabia (2 vols.), London.

Wheeler, A. and A.K.G. Jones. (1989). Fishes. Cambridge Manuals in Archaeology. Cambridge University Press.

White, A.W. and M.A. Barwani. (1971). Common Sea Fishes of the Arabian Gulf and Gulf of Oman. Dubai: Trucial States Council.

Whitelock, F. (1838a). An account of the Arabs who inhabit the coast between Ras el Kheimah and Abothubee in the Gulf of Persia, generally called the Pirate Coast. Transactions of the Bombay Geographical Society 1 (1836-38): 32-54.

Whitelock, F. (1838b). Notes taken during a journey in Oman along the east coast of Arabia. Transactions of the Bombay Geographical Society 1 (1836-38): 295-298.

Whitelock, F. (1838c). Descriptive sketch of the islands and coasts situated as the entrance to the Persian Gulf. Journal of the Royal Geographical Society 8 (1838): 170-84.

Wilkinson, J.C. (1964). A Sketch of the Historical Geography of the Trucial Oman down to the beginning of the Sixteenth century. The Geographical Journal 130: 337-349.

Wilkinson, J.C. (1977). Water and Tribal Settlements in South-East Arabia. Oxford.

Wilkinson, M. (1981). The use of fish in resource scheduling and seasonality studies in temperate latitudes. In: D. Brothwell and G. Dimbleby (eds.), Environmental Aspects of Coasts and Islands. BAR International Series 94, Oxford, 181-194.

Williams, T.P. (1986). Ageing Manual for Kuwaiti Fish. KISR 1915: MB-44. Mariculture and Fisheries Department, Food Resources Division, Kuwait Institute for Scientific Research, Kuwait.

Wilson, A. (1928). The Persian Gulf: An Historical Sketch from the Earliest Times to the beginning of the Twentieth Century. London: Allen and Unwin.

Wing, E.S. (1994). Patterns of prehistoric fishing in the West Indies. Archaeofauna 3: 99-107.

Wing, E.S. (1998). The sustainability of resources used by Native Americans on five Caribbean Islands. Paper presented at the 1998 International Council for Archaeozoology (ICAZ) conference, Victoria, British Columbia, Canada.

Wing, E.S. and Scudder, S.J. (1983). Animal exploitation by prehistoric people living on a tropical marine edge. In: Grigson, C. and Clutton-Brock, J. (eds.). Animals and Archaeology: 2. Shell Middens, Fishes and Birds. Oxford: BAR International Series 183, 197-210.

Wolda, H. (1981). Similarity indices, sample size and diversity. Oecologica 50: 296-302.

Woolley, Sir L. (1965). The Kassite Period and the Period of the Assyrian Kings. Ur Excavations Vol. VIII. Joint Expedition of the British Museum and of the Museum of the University of Pennsylvania to Mesopotamia.

Ye, Y., A.H. Alsaffar and H.M.A. Mohammed. (2000). Bycatch and discards of the Kuwait shrimp fishery. Fisheries Research 45: 9-19.

Yesner, D.R. (1980). Maritime hunter-gatherers: ecology and prehistory. Current Anthropology 21: 727: 750.

Yule, P. (1982). Lothal - Stadt der Harappa-Kultur in Nordwestindien. Materialen zur Allgemeinen und Vergleichenden Archäologie 9. C.H. Beck, Munich.

Zeder, M. (1974). Appendix B: Modern and ancient faunal record. In: A. H. Masry, Prehistory in northeastern Arabia: The problems of interregional interaction. Miami, Florida: Field Research Projects, 274.

Zohar, I. and R. Cooke (1997). The impact of salting and drying on fish bones: Preliminary observations on four marine species from Parita Bay, Panama. Archaeofauna 6: 59-66.

Zohar, I., T. Dayan, E. Spanier and O. Lernau (1994). Exploitation of grey triggerfish (Balistes carolinensis) by the prehistoric inhabitants of Atlit-Yam, Israel: a preliminary report. In: W. Van Neer (ed.), Fish Exploitation in the Past – Proceedings of the 7th Meeting of the I.C.A.Z. Fish Remains Working Group, 6-10 September 1993, Leuven. Annales du Musée Royal de l'Afrique Centrale, Sciences Zoologiques 274, Tervuren, Belgium, 231-237.

Zohar, I., T. Dayan and E. Spanier (1997). Predicting Grey Triggerfish Body Size from Bones. International Journal of Osteoarchaeology 7: 150-156.