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**THE ROLE OF THE TRADITIONAL MEDITERRANEAN DIET  
IN THE DEVELOPMENT OF MINOAN CRETE**

**ARCHAEOLOGICAL, NUTRITIONAL AND BIOCHEMICAL EVIDENCE**

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# THE ROLE OF THE TRADITIONAL MEDITERRANEAN DIET IN THE DEVELOPMENT OF MINOAN CRETE

## ARCHAEOLOGICAL, NUTRITIONAL AND BIOCHEMICAL EVIDENCE

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**ABSTRACT**

Archaeological evidence reveals that a diet consisting of mainly of cereals, pulses and olives, supplemented by fish and with a low percentage of animal products, was consumed on Crete in the Minoan period, as it was up to this century. Modern clinical and biochemical research indicates that this traditional 'Mediterranean diet' offers certain nutritional and health benefits depending on the balances of the components - particularly relating to moderately high carbohydrate intake, low saturated (mainly animal) fatty acids and the presence of beneficial fatty acids of vegetable (especially olive) and fish origin. It has been demonstrated that intake of these latter fatty acids is associated with reduction in cardiac pathology and the development of visual and mental acuity in neonatal infants. Beneficial effects in certain cancers and auto-immune diseases are also being investigated. Lipid analyses of samples of Cretan olive oil and Aegean fish (identified taxonomically from faunal remains and Minoan frescoes) confirm good levels of both essential and other dietary fatty acids. An assessment of the nutritional benefits of the Minoan diet and its possible role in the development of Minoan Crete are investigated, using archaeological, demographic, biochemical and skeletal evidence.

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## 1. INTRODUCTION

### 1.1 The need for a more scientific environmentally-based model for Aegean Bronze Age prehistory

The study to be undertaken is an investigation into certain specific nutritional components of the traditional Mediterranean diet, as defined by Keys *et al* (1957, 1965, 1986), Keys and Keys (1975), Keys (1970, 1980, 1997), Ferro-Luzzi and Sette (1989) and Spiller (1991a), using evidence from Bronze Age Crete as a basis for research. The approach adopted is multi-disciplinary and uses information obtained from archaeology and classical literature as well as food chemistry, botany and zoology.

The early nineteen seventies were in some respects watershed years for the study of Aegean Bronze Age archaeology. On one hand a lack of self-assurance was evident on the part of Aegean archaeologists together with recognition of the need to redefine future directions of study, whilst on the other hand increasing use was made of the physical and biological sciences as adjuncts to archaeological fieldwork. Furthermore, as doubts were being expressed on the validity of some of the older traditional approaches in Bronze Age scholarship, increased emphasis was given to the need to integrate Aegean archaeological finds into their environmental context. Contributing to this dilemma of the early Seventies was undoubtedly the fact that the study of Aegean Bronze Age archaeology is something of an academic hybrid that does not fit into any neat scholastic mould. On different occasions the study of Aegean archaeology may incorporate in addition to archaeology, classical texts, mythology and linguistics, as well as the physical and chemical sciences and even social and physical anthropology.

In a critical review article entitled 'The Greeks in history and prehistory' McNeal (1972 : 19-28) suggested that the study of Aegean archaeology was in a state of disarray and that a malaise was evident in the work of contemporary scholars. To emphasise this point he quotes Professor Doro Levi the excavator of the Minoan Palace at Phaistos as saying that he personally felt a fresh start was needed in the study of Bronze Age Crete. In a similar vein Professor Renfrew wrote in a Preface to his publication on the use of models in prehistory (1973) that it was now commonplace to speak of a crisis in archaeology or the need for a methodological reevaluation.

In the past two decades archaeological techniques have been considerably refined and the mass of archaeological evidence on Aegean prehistory has increased at an almost alarming rate. Notwithstanding this the comments of McNeal and Renfrew highlight two problem areas that are relevant to this present study of Minoan Crete. The first is what could amount to an over-extended use of allied or related disciplines to support archaeological hypotheses that on occasions are weak in construction. This particular problem is fortunately more applicable to earlier studies than those published *post-1970*. The second and more immediate problem was the need for a theoretical framework for the study of Aegean archaeology.

McNeal in particular is critical of some of the earlier attempts to obtain greater clarity by combining archaeology with other disciplines. One weakness he points to is that Aegean archaeologists usually approach prehistory from their own circumscribed speciality and have at times relied heavily on conclusions reached by scholars in what to archaeologists is an alien discipline. In this regard comparative linguistics probably offers greater pitfalls than other related fields of scholarship. An example of this was the paper 'The coming of the Greeks' (Haley and Blegen 1928), a pioneering study in which linguistic assumptions based on a migration theory were combined with archaeological evidence resting on a similar premise. Archaeologically the focus of attention was the distribution of the characteristic grey Middle Helladic Minyan pottery and the assumption reached was that Greek-speaking immigrants were associated with its introduction into Greece. Recommended to undergraduate students for some four decades and quoted by Vermeule (1964 : 334, 360), 'The coming of the Greeks' is now generally accepted as an injudicious blend of linguistic and archaeological theory and that the origins of Minyan ware lie within Greece itself (Renfrew 1972 : 56). The danger inherent in studies relying on a combination of linguistics and archaeology is that ethnic associations can all too easily intrude, fostered by the idea of the use of a single language.

In the foreword to his paper Professor McNeal apologises for the fact that the views he expresses on Aegean prehistory are largely negative and his message one of prohibition. Notwithstanding this cautionary note the use of multi-disciplinary studies in Aegean archaeology has increased considerably in the past two decades and the inventory of supporting evidence has widened to include the analysis of animal, fish and human remains, chemical analysis of organic residues and the archaeobotanical examination of seeds and pollen. Use of these scientific techniques at Myrtos, Palaikastro, Knossos and Anemospilia on Crete, Santorini and Saliagos in

the Cyclades and Lerna and elsewhere on the Greek mainland, has led to much improved social and economic reconstructions from the archaeological evidence.

Concurrent with this increased body of related knowledge has come changes in contextual emphasis in Aegean archaeological reports. Notably less use is now made of comparative linguistics and cultural parallels, both fertile fields for Aegean prehistorians earlier this century.

The move to a more science-based approach to Aegean prehistory has led to some interesting applications of chemistry and physics. At Myrtos an Early Minoan II coastal settlement in eastern Crete studies were undertaken to determine the source of pottery clay, the firing temperatures of the pots and the age of sherds (Warren 1972 : 261). In another interesting application of physical science to Aegean studies Charles (1972 : 134-139) used metallurgical techniques to demonstrate that a process for bonding silver to bronze, usually credited to Sheffield metalworkers of the 18th century AD, was used by the Minoans some three and a half millennia earlier.

New ground in Aegean Bronze Age studies was also broken by Cann and Renfrew (1964 : 111-133) using chemical analyses to trace the origins of obsidian, a dark vitreous substance used for tool-making in the Neolithic and Early Bronze Ages in the Mediterranean. Their analyses showed that there are four identifiable sources of workable obsidian in the Aegean; two at Adhamas and Dhemenegaki on the island of Melos 60 km south-west of Antiparos, one on the island of Giali near Nisyros about 180 km east of Antiparos and the fourth site is on Antiparos itself.

These examples of the application of chemistry or physics to Aegean archaeology demonstrate the kind of information that a more scientific approach offers. An important consideration is that the data collected are essentially quantitative rather than opinion orientated or qualitative.

The rise of environmental awareness in the Seventies has led to the identification and analysis of faunal remains found on Aegean archaeological sites. These analyses highlight both the agricultural and economic activities of the settlements as well as providing insight into some of the nutritional characteristics of the diet of the earlier inhabitants. At Myrtos for example an

assemblage consisting predominantly of bones of older sheep suggests that the animals were reared for wool rather than meat. Archaeological finds of loom weights and spindle whorls provide cultural confirmation of the faunal data (Warren 1972 : 27). At Saliagos near Antiparos in the Aegean analyses of both animal and fish remains were undertaken (Evans and Renfrew 1968 : 114-121). Over ninety per cent of the animal bones were from sheep emphasising the economic importance of these animals. Similarly the high percentage of tuna bones amongst the fish remains demonstrated that these large migratory fish were harvested for food consumption probably on a seasonal basis.

At Lerna on the Greek mainland the faunal analyses of animals and fish provided valuable information on temporal changes in the economic and dietary patterns of the Bronze Age community (Gejvall 1969). Analyses of the bone remains reveal for example that hunting and fishing declined markedly in the Middle Helladic period, to be replaced as the primary protein source by domesticated sheep and cattle. This realisation that faunal analyses can provide valuable quantitative data on diet and economy has recently led to the recovery of material from settlements where faunal remains were previously ignored. At Palaikastro on Crete a site with some ninety years of excavation history recoveries of bone show that the fish harvested were predominantly of the smaller sub-tropical Atlantic/Mediterranean species. The recovery of these remains (Mylona 1994, Appendix III) suggests that fishing constituted a constant though secondary food resource.

The use of archaeobotanical techniques in recent years provides further economic and nutritional data. Both at Myrtois and at Saliagos (a Middle Neolithic settlement) Jane Renfrew has demonstrated the kind of information that application of the natural sciences can provide on Aegean agriculture (Evans and Renfrew 1968 : 139-141; Warren 1972 : 315-317). At both settlements evidence suggests that wheat and barley were cultivated. At Saliagos fossilised grain and grain impressions in mud bricks provide evidence of cereal cultivation. At Myrtois in addition to the evidence for cereal cultivation, archaeobotanical techniques allied to radiocarbon dating provide evidence for the cultivation on Crete of the vine and olive in the Early Minoan period (c. 2200 BC). Additional evidence suggests that wine or olive oil was made (Warren 1972 : 26-27; 138-139).

Notwithstanding the pessimism voiced in the early Seventies, these examples of modern scientific techniques now used routinely in Aegean archaeology show that multi-disciplinary studies have increased and widened the scope of Aegean research. Studies have moved away from the use of migration theories as explanations for culture change to more goal orientated research that is often directed towards single cultural phenomena. These may include agriculture, fishing, diet and the more technical crafts such as pottery-making and metallurgy. Concomitant with the general downturn in funding for archaeology current projects would probably involve archaeological fieldwork, the recovery of artefactual or biological material, followed by laboratory examination. It must be pointed out however that though scientific techniques provide answers, these tightly defined studies could possibly miss more diffuse yet significant factors that characterise or determine a particular culture.

Winder (1991 : 48-50) in his reassessment of the Knossos Neolithic settlement has reservations on scientific methodology and criticises the lack of theoretical concepts and tardy publication that has accompanied its introduction. He points to the general acceptance today of the idea of an archaeological 'backlog' and the accumulation of a mass of raw undigested data nestling in computers as a substitute for the earlier era of hypothetical reconstruction and publication.

The point at issue is perhaps that procedures introduced into Aegean prehistory from the natural and physical sciences should ideally be used to answer specific questions and not simply to generate data that might be of peripheral interest.

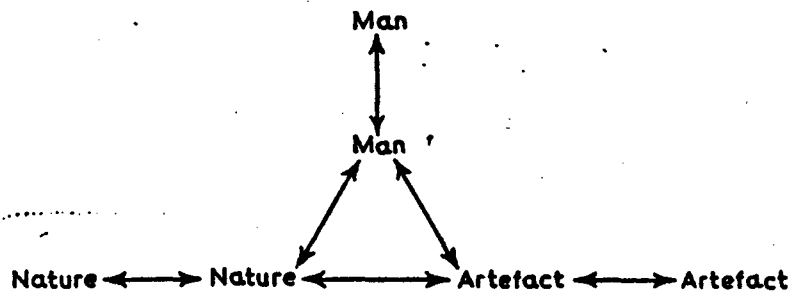
The second important point raised by both McNeal and Renfrew in the early Seventies was the need for a theoretical structure for the study of Aegean prehistory. McNeal suggested in this context that by and large the premise on which an interpretation of Aegean prehistory was based was rarely given a careful and explicit formulation. Any premise was usually implicit in the archaeological report. Commenting that the classical archaeologist is especially unfortunate in this regard, he qualified his statement by admitting that a lack of theory is by no means confined to Mediterranean archaeology and conceded that social anthropologists also lament the shortage of studies on method.

It is significant that McNeal's criticism of the lack of a theoretical structure for Aegean archaeology coincided with the publication of Renfrew's 'Emergence of Civilisation' (1972). This publication proposed a systems model for Aegean archaeology tested against the rise of the Bronze Age Minoan civilisation on Crete. In Renfrew's model man, artefact and natural objects comprise the primary components and archaeology, natural, physical, chemical and social science provide evidence for interaction between the component parts. The model was thus not static but dynamic in conception.

Figure 1 illustrates schematically the basic components of the proposed model. Six kinds of interaction are shown, five of them within the culture system and one (Nature  $\leftrightarrow$  Nature) outside of it.

FIGURE 1

Schematic model based on systems analysis for Aegean prehistory  
(Source: Renfrew 1972 : 19, Fig. 2.1)



For purposes of his analysis Renfrew identified the following subsystems:

- (a) The subsistence subsystem  
Man and his food resources are interrelated by subsistence orientated activities.
- (b) The technological subsystem  
This subsystem is comprised of men, the material resources and finished artefacts.
- (c) The social subsystem  
This system is based on inter-personal behavioural patterns.
- (d) The projective or symbolic subsystem  
This subsystem includes religion, art, language and science. Essentially it covers the ways in which man gives formal expression to his understanding and reaction to the world.

(e) Trade and communication

This subsystem is defined as all those activities by which goods are transferred between settlements. It includes all movements of components of the system whether men or artefacts.

It must be pointed out however that the boundaries between these sub-systems are difficult to define at times since human action can obviously exist in several dimensions at once.

Population levels and technical innovation in the model are seen as key factors to its functioning. With technical innovation growth usually occurs in a subsystem and this in turn is reflected in an increase in population. Population is not seen as a subsystem but is a parameter, the value of which is influenced by, and in turn influences, each of the subsystems. Major Bronze Age innovations include the introduction of metallurgy and the domestication of the vine and the olive.

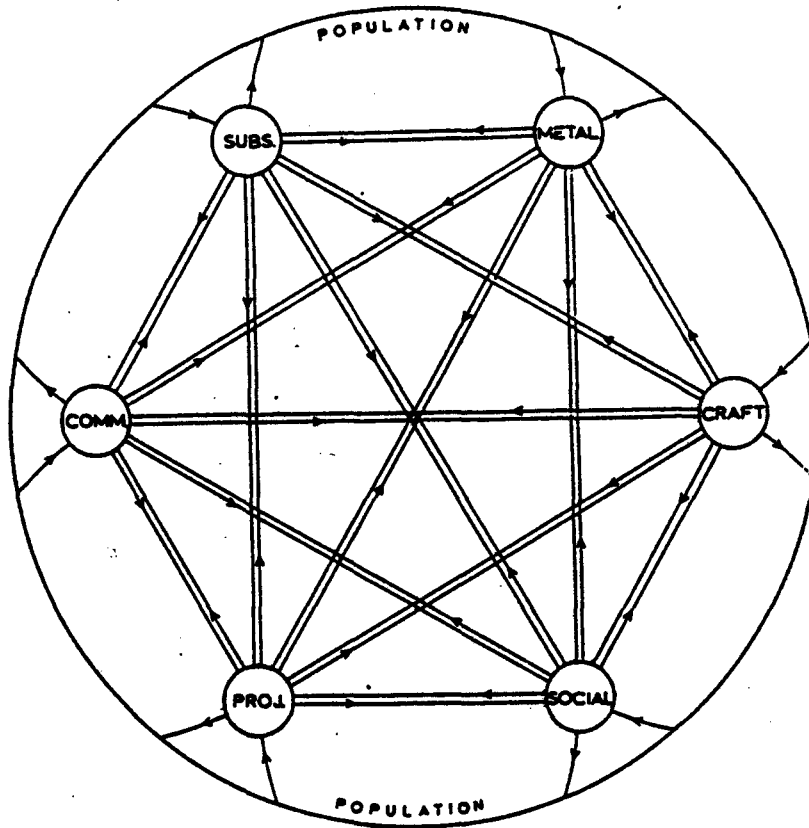
Interestingly though, Branigan is of the opinion that the introduction of copper and bronze had a limited effect on agriculture in which soft metal tools would have been little or no improvement on the earlier stone or bone counterparts with the exception of sickles which begin to appear in small quantities. Fishing, however, did appear to benefit with the introduction of the copper fish hook and possibly lead line sinkers and copper needles for making and repair of nets. Metal spearheads and the first metal arrow heads doubtless also benefited the hunter (Branigan 1974 : 133).

The introduction of vine and olive would have been a gradual process and Sallares (1991 : 306), opposing Renfrew's views, prefers to see olive cultivation in Greece, other than Crete, restricted to the first millennium BC. He points out that if Cretan olives were obtained from the Levant, the use of systems theory to explain the rise of Minoan civilisation is injudicious, since the methodology should not be used to predict novelties obtained outside the system.

Figure 2 shows how interaction takes place between the different subsystems in the model proposed by Renfrew for Aegean prehistory.

FIGURE 2

Schematic model showing interactions between the subsystems of the Aegean culture system (Source: Renfrew 1972 : 486, Fig. 21.1)



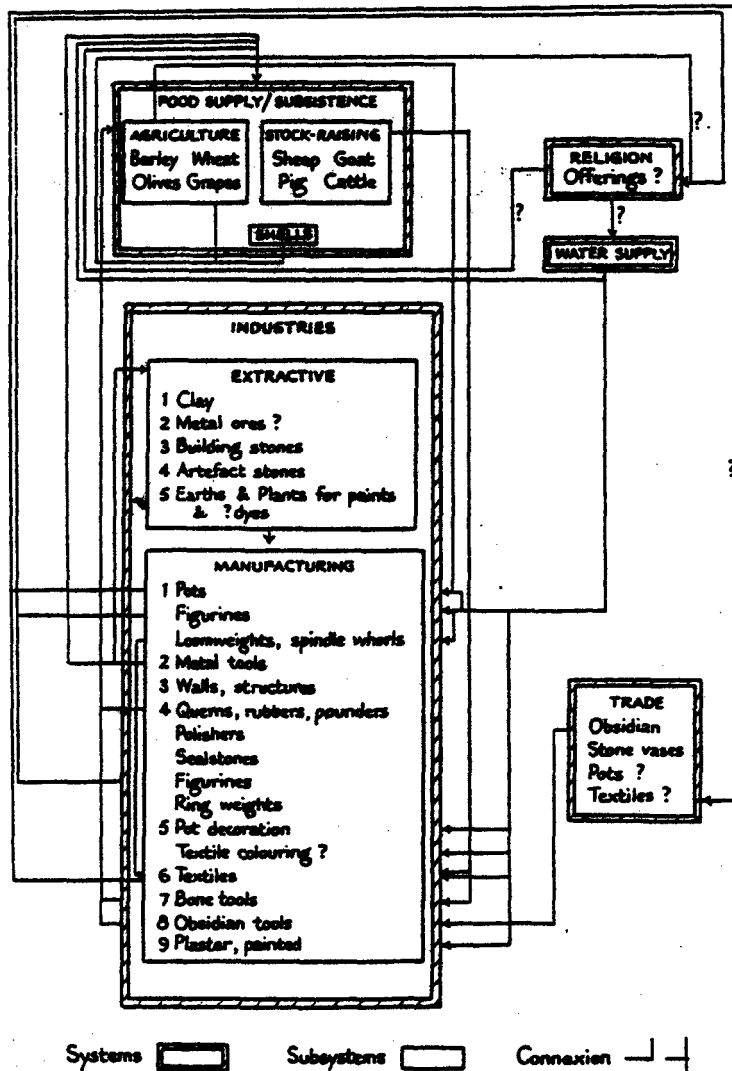
Innovation stimulating positive feedback results in growth and development in the society.

The publication of 'The Emergence of Civilisation' (1972) and its accompanying theoretical basis is reported to be the first attempt to analyse in detail the emergence of an ancient civilisation. It is noteworthy that Renfrew's first priority as an archaeologist was to collate and review the archaeological evidence. The review forms Part I of the publication. Once this was completed an attempt was made to construct from the archaeological data a picture of the culture processes at work and the changes that resulted. 'The Emergence of Civilisation' combines the application of the systems model outlined above with a multi-disciplinary approach along the lines advocated earlier. Textually the results achieved are more informative than the broad speculations and cross-cultural comparisons published earlier which sometimes failed to identify the innate complexities of particular social processes.

Two monographs, the one on Minoan Crete and the other dealing with the Greek Mycenaean region of Messenia, were published coincidentally with the contributions of McNeal and Renfrew. Both these monographs confirm the value of scientifically based multi-disciplinary studies. The publication on the Early Minoan II coastal village of Myrtos in eastern Crete combines the techniques of traditional Aegean archaeology, that is excavation, theoretical architectural reconstruction and pottery analysis with fairly extensive use of the natural, physical and chemical sciences (Warren 1972). Study of the physical geography of the region, analysis of the faunal and botanical remains and chromatographic analysis of pottery clay were for example all done by specialists. This combination of traditional archaeology with scientific and environmental studies was then placed in context against the theoretical systems model shown in Figure 3.

FIGURE 3

Model of reconstruction of the Myrtos living system  
(Source: Warren 1972 : 264, Fig. 108)



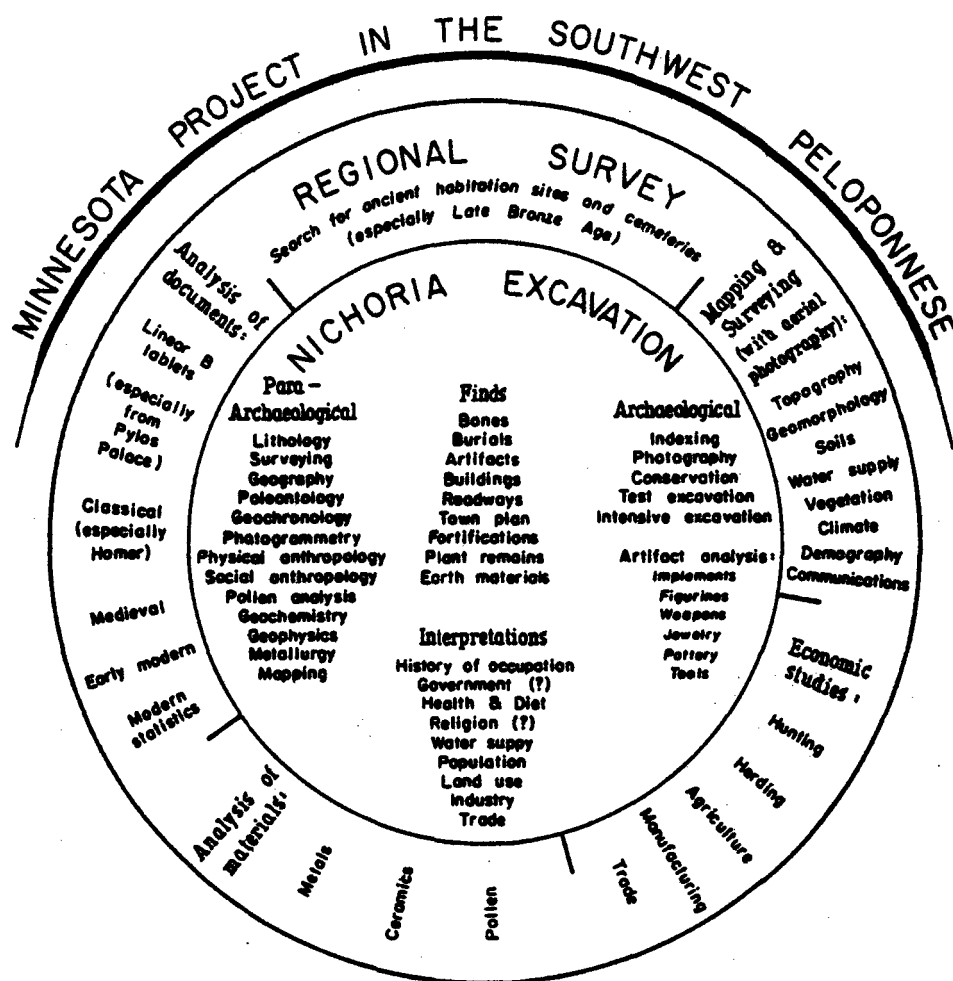
The model proposed by Warren as the basis for an analysis of the community's activities at Myrtos (Fig. 3) shares similarities with that put forward by Renfrew for Minoan Crete, in particular both models are based on a structure of interconnecting systems and subsystems. Significantly however the model for Myrtos is a more static concept while the scheme for Minoan Crete as a whole as is to be expected from the title 'The Emergence of Civilisation' is of a more evolutionary nature. At Myrtos the settlement area is some 1250 square metres and the population was estimated by Warren (1972 : 267) to be 100 to 120 people but by Whitelaw (1983 : 323-345) to be 25 to 30 on a different interpretation of the site. The proposed model which confines activities to those appropriate to a small scale innately conservative community is therefore entirely applicable. As a glance at the model reveals procurement of food appears to have been the first priority and it took precedence over industrial and trading activities. The Myrtos model thus applies to a community that was primarily subsistence orientated.

As if in reply to the appeal in the Nineteen Seventies for a more theoretically structured approach to Aegean prehistory yet another model was proposed (McDonald and Rapp 1972a), this time for the later Bronze Age region of Messenia in the south-west Peloponnese. Supported by a wide range of archaeological and classics-based disciplines set against a sound scientific and environmental background this monograph is certainly one of the more comprehensive regional reports on the Greek Bronze Age. Research is both synchronic and diachronic and since it is primarily concerned with the later Mycenaean period it was possible to make extensive use of the Linear B Tablets, the Homeric poems and the later classical writers. Regional census figures and even modern population statistics are used to provide quantitative comparative background information.

Figure 4 shows the comprehensive theoretical model against which the fieldwork and studies in Messenia were carried out.

FIGURE 4

Theoretical structure of regional survey and archaeological excavations carried out in Messenia (Source: McDonald & Rapp (eds) 1972 : 6, Fig 1-1)



The model for the Messenia study is strongly ecologically orientated, covering soils, water supply, vegetation, communication and geomorphology, this being so because of the survey's archaeo-geographical nature.

The work was broken into three phases with the first being concerned with modern records. The program required:

- Examination of later documented material (census records, agriculture and land records) to obtain useful insights into the historic past.
- Analysis of the most relevant archaeological evidence from the later Bronze Age.
- The use of different scientific techniques to throw light on various features and physical characteristics of the Messenia landscape and physical environment.

The theoretical model proposed for the examination of the Late Bronze Age and later historic period in Messenia thus highlights the ancient physical environment and human adaptation to it. The monographs for Myrtos and Messenia both emphasise this relationship but the Messenia study is the most comprehensive.

The study of classical archaeology in the past has aroused criticism for being eclectic, unscientific and lacking in any proper theoretical structure (McNeal 1972; Renfrew 1973; Van der Merwe 1976). Publications on the Aegean Bronze Age indicate however that these demands for a theoretical and structured approach have gained considerable support over the past two decades. Whereas McNeal (1972), Renfrew (1972), Ammerman and Cavalli-Sforza (1973, 1984), Bintliff (1977a, 1984), Sherratt (1981) and Hodder (1982) were amongst earlier contributors offering a more critical approach, recent authors include Cherry (1982, 1983, 1990), Snodgrass (1985), Halstead (1987, 1992), Runnels and Van Andel (1987, 1988, 1995), Gallant (1991), Sallares (1991) and Watrous (1982, 1987, 1994). Contributions by these later authors as well as the more salient points made by the earlier writers will be dealt with in the relevant sections. The past twenty-five years have also seen greater use made of natural and other scientists on Aegean archaeological excavations. Following the important reports of cereal and caprini remains from the Early Neolithic levels at Knossos by John Evans in the 1960's (1964 : 132-240, 1968 : 267ff and 1971 : 95-117), similar techniques were used in the excavation of the Middle Neolithic settlement at Saliagos in the Cyclades, the intention being to reconstruct the farming and fishing patterns of the early island community. Publication of the Saliagos findings (Evans and Renfrew 1968) was followed by the comprehensive archaeological and environmental report on the Early Minoan settlement of Myrtos in eastern Crete (Warren 1972). Recently Middle/Late Minoan fish remains recovered from Palaikastro at the extreme eastern end of Crete have been identified and analysed (Mylona 1994, Appendices I-III). Data from these three Aegean settlements together with further information from others constitute the evidence for discussion on the nutritional role of cereals, olives and fishing on Minoan Crete.

The intention in this brief discussion on approaches and methods used in Aegean Bronze Age studies was to show both the critical attitude adopted by Aegean scholars since the Seventies as well as the progress made towards a more structured and scientifically based discipline.

## 1.2 The research approach adopted in this study

The study that follows is an attempt to use Bronze Age Crete as a basis to investigate specific dietary and biochemical characteristics of three primary components of the traditional Mediterranean diet, viz. cereals, olives and fish. The traditional Mediterranean diet is high in cereal content (some 30 to 60 per cent of the daily calorie intake is from cereals), low in saturated animal fat and contains copious quantities of olive oil (Spiller 1991a). Renaud *et al* (1995 : 1365S) emphasise the value of fruit in the contemporary Mediterranean diet. In the Aegean fish has also traditionally provided an important source of protein. The diet consumed on Crete which until recently remained unchanged for some four thousand years has a similarly high cereal content (primarily wheat and barley), is low in saturated animal fat, has a high olive oil content and is supplemented by fishing (Allbaugh 1953). Archaeological and literary evidence to be presented confirms that diet and nutrition on Bronze Age Minoan Crete conformed to the traditional Mediterranean diet as described by Allbaugh 1953, Renfrew 1972, Warren 1972, Keys 1970, 1980, Keys *et al* 1986 and Spiller 1991a. While consideration in this research is given to the role of cereals on Crete, more specific attention is directed to the identification and determination of the important essential fatty acids present in traditional cold-pressed Cretan olive oil and the lipids of fish caught in the Mediterranean and the Aegean.

The presence and levels of these fatty acids in particular docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) are of considerable nutritional interest to both Aegean prehistorians and contemporary medical scientists active in nutrition.

The research that follows draws for both structure and methodology on the three models proposed for Aegean prehistory described earlier. Discussion on population growth in the Aegean as an indicator of the spread of agriculture and improved nutrition draws on the theory outlined by Renfrew in 'The Emergence of Civilisation'. The archaeo- environmental study for Messenia provided guidance on the interrelationship between Aegean coastal communities, fishing and agriculture. The Messenia report because it deals with the later Mycenaean period also provided the opportunity to compare the validity of information derived from the later classical literary sources and Linear B texts against that obtained by conventional archaeology. In this context comparative studies on regional population densities in Messenia using both Linear B texts and the archaeological data proved informative.

The use of chromatography to determine the fatty acid composition of olive oil and fish lipids has a precedent in Warren's publication on Myrtos, where an unsuccessful attempt was made to detect olive oil residues in pottery recovered by excavation.

FIGURE 5

Abridged scheme for primary areas of research

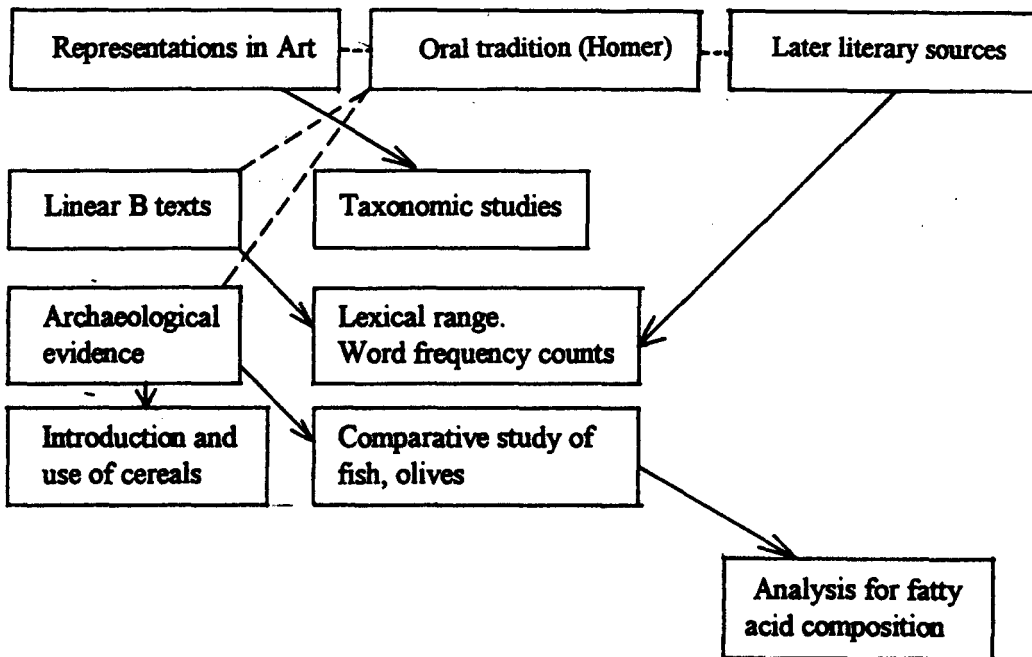
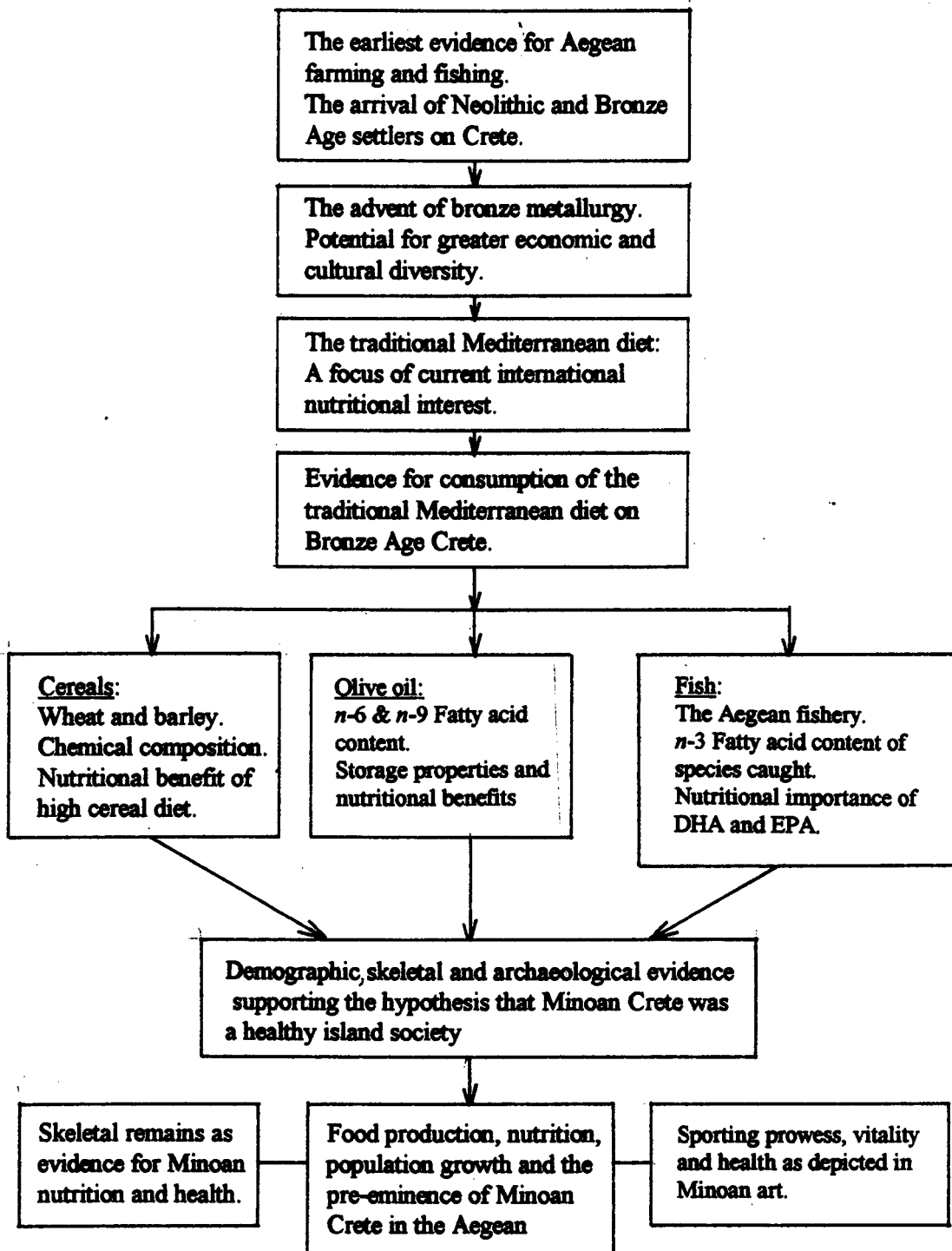


Figure 5 illustrates the five primary sources of evidence used in this study. The evidence comprises archaeology, art, the Linear B tablets, oral tradition and literary sources. It must be pointed out that written records which include Homer possibly date from as late as 700 BC. There is a presumption however of an earlier oral tradition extending back to the Bronze Age. The written sources together with some hundred years of Aegean archaeological research contribute information on cereal production, olive growing and fishery practices. Modern fishery science provides comparative taxonomic data. Analytical chemistry supplies quantitative information on the lipid composition of both olive oil and the different Aegean and sub-tropical Atlantic fish species.

Figure 6 shows the proposed structure for the study of the potential health benefits attributable to specific components of the traditional Mediterranean diet.

FIGURE 6

The evidence for cereals, olives and fish in the traditional Cretan diet and their chemical analysis for fatty acid composition and content

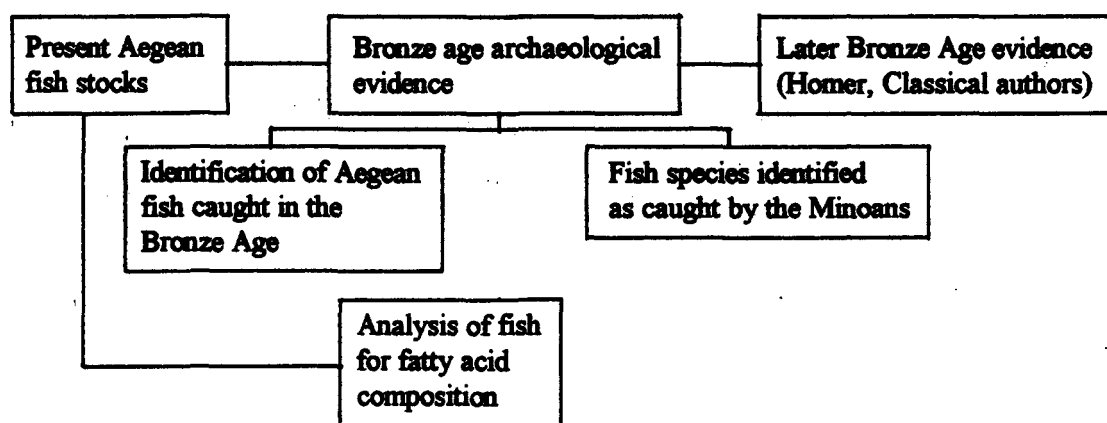


The introductory discussion on the earliest evidence for farming and fishing in the Aegean, as well as the section following on economic changes brought about by the onset of metallurgy draws mainly on conventional sources of archaeological material. Discussion on olive cultivation and olive oil production on Minoan Crete in addition to using archaeological evidence utilises modern scientific data published by olive research institutes situated in Spain and on Crete. Allbaugh's 1948 survey of Crete as an under-developed region provides agricultural background (Allbaugh 1953). Chemical analysis of the Aegean olive oil samples for fatty acid composition and content was done by the Fishing Industry Research Institute, Rosebank, Cape Town using the Institute's standard gas chromatographic procedure detailed in the Appendix.

Research into the fish caught and used for human consumption in the Aegean Bronze Age was both wide-ranging and comprehensive. Figure 7 shows the methodology employed for this part of the work.

FIGURE 7

**Identification of fish caught in the Aegean Bronze Age  
and analysis for fatty acid composition**



Preliminary study involved a survey of the present-day Mediterranean and Aegean fisheries using mainly statistics issued by the United Nations Food and Agriculture Organisation, Rome. In addition to providing an objective view of the fishery this information gave a more accurate insight into the type and extent of fish stocks harvested in the Bronze Age. This was followed by an analysis of fish faunal and artefactual remains recovered archaeologically associated with fishing at different Bronze Age Aegean settlements, these being situated on Crete

notably Palaikastro, Gournia, Myrtos and Knossos, the Cycladic islands and in particular Lerna on the Greek mainland. Supplementary and comparative evidence was provided by a survey of references to fishing contained in the Homeric and later classical literature. By combining modern fishery data, archaeological evidence and Homeric and classical source material the intention was to obtain the widest possible evidence for the species and range of fish harvested in the Aegean Bronze Age with, particular emphasis placed on fishing off Crete in the Minoan period.

A fortuitous occurrence and a contributory factor that inspires confidence in the nomenclature and taxonomy of the fish identified in the tables presented in the relevant section is that many of the pelagic, demersal and littoral species of Mediterranean and Aegean fish have their counterparts along the South African south and south-west coasts. The reason for this is that the two geographic regions are climatically similar, both have Mediterranean climates and both have primary fish populations made up of sub-tropical Atlantic species. Fish common to the southern Cape, the Mediterranean and the Aegean include Spanish mackerel *Scomber japonicus*, horse mackerel *Trachurus trachurus*, dolphin fish *Coryphaena hippurus* and the Cape 'dassie' *Diplodus sargus*. Faunal remains of this last species which is widely distributed around the African coast and in the Mediterranean were for example recovered at Palaikastro in Middle/Late Minoan strata (Mylona 1994, Appendix III). Also common to both regions are many of the tunas notably bluefin *Thunnus thynnus*, albacore *Thunnus alalunga*, the bonito *Sarda sarda*, frigate tuna *Auxis thazard*, the Atlantic little tuna *Euthynnus alletteratus* as well as the swordfish *Xiphias gladius*.

Dr Ackman (pers. comm.) queries the stability of the Mediterranean and Aegean fish stocks. This question is dealt with in some detail under Section 6.1 "The topography, hydrography and potential fish stocks of the Mediterranean and the Aegean". Discussion based on fishery data published by the United Nations Food and Agriculture Organisation (FAO) (Gulland 1971 : 42, Table C.4) indicates that fish stocks are reasonably stable. Recently catches have increased from 115 000 metric tons in 1985 to 140 000 metric tons in 1990 (Karakoltsidis, Zotos and Constantinides 1995 : 259-260), which may give cause for concern in the future.

Where evidence indicated that these and other species were caught in the Aegean Bronze Age their commonalty in Cape waters ensured that little difficulty was experienced in obtaining

specimens and correctly identifying them taxonomically. Fish taxonomy is an imprecise science and in some instances fish identified by researchers as being caught in the Aegean could not be classified either as a Family or sub-species. Fish referred to in the literature on Mediterranean Aegean prehistory were also found to be wrongly identified, for example the common skipjack tuna (*Katsuwonus pelamis*) is confused by Gallant with the Mediterranean bonito (*Sarda sarda*) (Gallant 1985 : 54).

Once the fish had been identified fresh or frozen specimens were obtained to enable determination of their fatty acid composition. Few difficulties were experienced in obtaining those species available off the Cape coast. Less common fish such as the dolphin fish *Coryphaena hippurus* were obtained from freezer trawlers operating from Cape Town. Samples of fish specific to the Mediterranean for example the sardine *Sardinella aurita* were fortuitously obtained from Russian trawlers fishing off the coast of North Africa. These fish formed part of commercial catches landed at Walvis Bay, Namibia, and were flown frozen packed in insulated boxes down to Cape Town. Where specific fish were unobtainable previously published fatty acid composition data had to be used.

Provided the identifications of the fish are correct no major differences in fatty acid composition of similar fish from the different regions are envisaged. Various published comparative figures on crude fish oils from similar fish species caught off South Africa, South America and Europe generally show only marginal differences in fatty acid levels, these probably being associated more with seasonality and feeding than with regional differences (Young 1988 : Appendix 2). Dr Ackman notes (pers. comm.) that while the fatty acids of the phospholipids of very lean fish muscle are always comparable, the fatty acids of the fish body oil may change depending on food sources. Dr Ackman points out that while a ratio of 22:1 > 20:1 totalling 20-35% of fatty acid is common in the oil of North Atlantic herring eating copepods, menhaden within a few hundred miles eat no copepods and have almost no 22:1 in their body oil. The figures obtained were subjected to computer analysis and the results obtained are presented in the relevant section. All the fish fatty acid composition analyses were done at the Fishing Industry Research Institute again using the method contained in the Appendix.

The final part of the research outlined in Figure 6 involved assessing as objectively as possible just how healthy the Bronze Age Cretans were, in context of the evidence presented for

a sound diet. Information in the form of medical studies on Minoan skeletal material is available from the work of McGeorge 1988 : 47-54, 1990 : 419-428, Halstead 1977 : 107-111 and Wall *et al* 1986 : 333-388. With regard to demographic data Renfrew (1972 : 251, Table 14.IX) has shown that the calculated expansion of the Minoan population was greater than at Cycladic and mainland sites in the Aegean Bronze Age. This estimated increase in population coincided with technical improvements in Cretan agriculture, a so-called secondary products revolution (Renfrew 1972 : 38-44; Van Andel and Runnels 1988 : 234-247; Sherratt 1981 : 261-305; Halstead 1992 : 105-116) and an expansion of settlements.

The discussion and analyses that follow are essentially exploratory in nature and break new ground in classical archaeology by investigating in some detail certain specific components of Aegean Bronze Age diet using Minoan Crete as a basis. The need to draw on evidence from such diverse disciplines as archaeology, classical texts, analytical chemistry and modern medicine dictates that certain results be presented qualitatively rather than quantitatively, which would have been the more desirable.

## 2. THE ARCHAEOLOGICAL BACKGROUND

### 2.1 The earliest evidence for agriculture and fishing in the Aegean

Farming and fishing are the two primary socio-economic activities that characterise most maritime and island communities. In Greece and the Aegean islands crop cultivation, particularly the olive and vine, the harvesting of fish and animal husbandry remain traditional activities. The roots of the latter two occupations extend well back into the Neolithic period while the olive and vine were not cultivated until the Bronze Age. Fishing, however, extends even further back into the Palaeolithic period. Archaeological evidence of this earlier period of hunter gathering, still scanty in Greece although increasing with new excavations and surveys, comes from a few sites at caves, rock shelters and open sites by lakes and rivers which would have been occupied by groups moving about to search out the best food resources (Dickinson 1994 : 30). The earliest evidence for fishing in the Aegean probably comes from Klithi cave in Epirus where fish remains were radiocarbon dated to between 15000 and 10000 BP (Bailey 1992 : 18-20).

It is reasonably certain, in spite of various claims, that there is no incontrovertible evidence for Palaeolithic or Mesolithic occupation on Crete (Cherry 1990 : 158). Although the decimation of the Mesolithic fauna on the island by hunting bands, as suggested by Moody (1987 : 145, *cited* Cherry *ibid* : 163), is an interesting possibility, there is no supporting data of any kind (Cherry *ibid* : 159).

The evidence for the evolution of human socio-economic activity in the Aegean must therefore be sought on the mainland of Greece. The Franchthi cave near Porto Cheli in the southern Argolid, where excavation has been carried out since the mid-1960s by the team led by Dr Thomas Jacobsen with palaeobotanical analyses by Dr Julie Hansen (1991), is still the best documented and the only known consistently occupied site from the Upper Palaeolithic to the Neolithic (i.e. from c. 20000 to 3000 BC) except for a break for a few thousand years around 15000 BC, which provides archaeologically intelligible stratigraphical sequence for this period (Jacobsen 1969 : 345-381, 1981 : 303-317). The evidence from elsewhere in Greece hardly alters the picture of social and economic conditions provided by the Franchthi data.

Archaeological excavation indicates that the cave was occupied as a base camp, initially probably seasonally, by a small band of hunter-gatherers, probably between 25 and 30 people. The earliest level belonging to the Palaeolithic coincides with the last glaciation; sea levels would have been depressed by as much as 100 metres and the geomorphology of the Aegean consequently markedly different (Van Andel and Shackleton 1982 : 445-454). Stone tools were small and local, the primary food source wild ass and red deer. There is no evidence of gathering of wild plants (Jacobsen 1981 : 306). Since the site was, at that time some distance from the sea, any possible fishing or shell collecting would probably have taken place away from the cave and any evidence of these activities is therefore lacking (Jameson, Runnels and Van Andel 1994 : 334).

During the Final Palaeolithic period c. 13000 - 10000 BP, post-glacial climatic changes and melting ice had raised the level of the sea somewhat and there are for the first time clear indications of small-scale fishing and shell collecting and the exploitation of wild plants supplementing the primary quarry of wild ass and deer. The plants included the pulses (lentils and vetch), nuts (pistachios and almonds) and wild cereals (oats and barley) the earliest yet recorded in Greece. At the same time there are the first certified indications of the use of obsidian (Perles 1979 : 82-83, *cited Jacobsen *ibid* : 306*) which came from a deposit of obsidian on the northern side of Melos some 150 km away. This use of obsidian at Franchthi cave antedates by at least 1000 years the earliest known occurrence of the material anywhere else in the Aegean (Jacobsen 1976 : 78).

The presence of obsidian is particularly interesting in that its sourcing from the island of Melos implies that at least some members of the hunting and gathering population in the Aegean had taken to boats before about 11000 BP (Angel 1971a : 21; Jacobsen 1981 : 306).

By the Mesolithic i.e. c. 9000 - 8000 BP, a continually rising sea level had diminished the available coastal land still more bringing the cave to within a few minutes walk of the shore and possibly reducing the amount of game. Red deer, wild pig and small prey were hunted and nuts, land snails, fruits, legumes and, for the first time, cereals were collected (Hansen 1991 : 119). An innovative stone tool kit including those traditionally associated with the Neolithic period had evolved (Cullen 1995 : 274) which could suggest the possibility of experimental manipulation of oats, barley and legumes prior to the Neolithic. There is also evidence for increased engagement

with the sea, particularly the quantities of marine molluscs and large fish bones which suddenly begin to appear. These have been identified as mainly from the common bluefin tuna (*Thunnus thynnus thynnus*) and would have reflected the harvesting of the annual spawning migrations of these fishes and the albacore (*Thunnus alalunga*) into the Mediterranean (Laevestu and Rosa 1963 : 3, Figs 1 & 5). The bones indicate fish of a size reaching as much as 2,5 metres in length and 200 kg in weight. Tuna vertebrae comprise 95% of fish bones and nearly half of the large animal bones. The method of catching is not clear but Jacobsen makes an interesting tentative connection with the increased finds of Melian obsidian possibly indicating that the fish were killed with obsidian tipped wooden spears although this is pure speculation. Since tuna schools do not approach closer to the shore than 100-200 metres (Jameson, Runnels and Van Andel *supra* : 314) this activity must have taken place from boats unless the fish were driven to the shore and trapped. This evidence indicates that fishing provided an important part of the Aegean diet in the period immediately preceding the Neolithic.

The people at this stage also began to place some emphasis on personal adornment with shell beads and pendants and practised the first mortuary rituals with inhumations and cremations of the dead (Cullen 1995 : 274).

Around 8000 BP the Neolithic period began at Franchthi cave showing "both continuity and change". Sheep and goats, both exotic, suddenly appear and quickly dominate the faunal remains. Emmer wheat, einkorn wheat and possibly two row hulled barley, not previously present, were now demonstrated and some of the indigenous plants virtually domesticated. It is clear that both plant and animal husbandry were practised and that food production had largely overtaken hunting and gathering as the base of the economy. Evidence for fishing declined as alternative resources were utilised (Jacobsen *supra* : 308).

At the same time the first clay pots, among the earliest in Greece, began to appear as now impermeable containers were required. Made without a wheel, this simple generally undecorated ware resembles pottery found at a number of comparatively early sites in the eastern Mediterranean area (Jacobsen 1976 : 76-87).

Contacts between the people at Franchthi and other areas (principally the Aegean islands), previously initiated, seem to have been expanded and intensified when the Aegean islands became

settled in the Later Neolithic period although the extent of formalisation of trade is unclear (Jacobsen 1981 : 310).

Outside the cave and along the shoreline (Paralia) there is evidence of a complex of substantial stone walls at least some of which appear to be domestic indicating the presence of a settled population which Jacobsen estimated as numbering about 100. Since at this time the sea had not quite reached its present level some of this site is partially submerged. At 6000 BC the sea level was about 25 metres lower than today and gradually rose to about the same level as today at c. 3000 BC (Van Andel 1989 : 733-745, 1990 : 152) although there is much local variation. There is, therefore, a possibility that Mesolithic and Neolithic sites could have been submerged and not yet recovered (Jameson, Runnels and Van Andel *supra* : 339). The site was abandoned in about 3000 BC.

Jameson, Runnels and Van Andel suggest strongly that the Neolithic economy was introduced into the southern Argolid from elsewhere in Greece or further afield stating that "the weight of currently available evidence favours the intrusive appearance of a Neolithic village with an economy based on a suite of cultigens of Near Eastern origin" (*ibid* : 341).

Earlier Dettel (1983 : 154-157) had pursued his "indigenest" theories to argue that, in common with other European Mesolithic sites showing incipient sedentism, the Neolithic development at Franchthi was a local phenomenon. Jacobsen was unwilling to commit himself as to whether Mesolithic incipient sedentism was an inevitable precursor to the Neolithic stage and remarked that it was "perhaps safest to reserve judgement on these issues and refrain from advancing too quickly diffusionist or migrationist models to explain the data" (1981 : 315).

The academic debate involving hypotheses for the origins and spread of agriculture has continued for a long time, particularly since the 1950s when interest in the subject really accelerated, and is still partially unresolved. In the European context the propositions relate to either an indigenous development of farming based on local and imported cultigens and domesticates (Dettel 1983, Barker 1985) or a farmer colonisation involving small scale migrations from the Near East (the 'wave of advance model' of Ammerman and Cavalli-Sforza 1984) or a mixture of the two (Zvelebil 1986).

Also around 6 000 BC, the first farming settlements in the Aegean other than the Franchthi cave were established in Thessaly on the mainland, the island of Cyprus in the eastern Mediterranean and at Knossos in Crete.

It is necessary to pay some attention to the long Neolithic period in Crete, beginning at Knossos, because it is during this period that a way of life was established based on the farming economy which was to endure into and beyond the Bronze Age (Dickinson 1994 : 33).

## **2.2 The arrival of settlers on Crete: the Neolithic to the Bronze Age**

Almost contemporaneously with the appearance of Neolithic farmers at Franchthi, the first settlers arrived in Thessaly and Crete. As far as Crete is concerned, however, there can be no dispute as to whether or not the settlement of the island was the result of migrant colonisation. Even at the period of greatest sea level recession in the last Ice Age, no land bridge to Crete existed and access to the island has always required sea-going ability (Van Andel and Shackleton 1982 : 445-54). As indicated previously, no definite evidence of pre-Neolithic occupation has been found, unlike the other Mediterranean islands of Corsica, Sardinia and Cyprus (Cherry 1990 : 163). It seems unlikely, however, that the existence of Crete was unknown. Intentional or accidental visitations entailing short-term occupation are probable, in the light of the migrants' apparent knowledge of the island in their planning of the settlement expedition (Broodbank and Strasser 1991 : 235).

The same authors also point out that the 7th Millennium settlement of Crete is significant as it was the first Aegean island to be settled and represented one of the earliest areas outside the Near East with evidence of village farming. It also represents one of the earliest successful maritime transfers of a full farming economy (*ibid* : 234). The type and number of boats used to transport sufficient numbers of people to start a successful colony together with large animals is still a matter of speculation (*ibid* : 233-245). What could have been significant for the future development of the settlement, however, was the quality of the original settlers themselves. It can be argued that all through history, those who choose to leave their homelands and settle elsewhere are among the bravest and most resourceful members of society. In order to succeed

in a strange country they need to apply themselves with extraordinary commitment, energy and courage.

Knossos was the site of the first and, at all stages subsequently the major, settlement some 5 km from the sea near the modern town of Herakleion. The location of Knossos is of interest in that it lies at the southern edge of one of the largest arable areas and is surrounded by and suitable for rough grazing. In the immediate vicinity of Knossos the land is highly workable and relatively fertile with the Kairos stream immediately below the site; also the permanent spring adjacent to the site, destroyed relatively recently by volcanic activity, could have been present at that time. The selection of the site demonstrates the high level of agricultural awareness possessed by the colonists (Jarman *et al* 1982 : 147).

An example of wood from Stratum X, the lowest excavated level at Knossos gave a C-14 date of  $8050 \pm 180$  BP (Evans 1964 : 136) and was associated with remains of ovicaprines, cattle and pig, emmer, barley and possibly bread wheat (*Triticum aestivum*) (Evans 1968 : 269 cited Broodbank and Strasser 1991 : 236) none of which are native to Crete. Other dates for this stratum are  $7910 \pm 140$  and  $7740 \pm 140$  BP. (Radioactive carbon dates are from Cherry 1990 citing J. Evans datings published between 1963 and 1982.) Scanty stone tools and obsidian were also present in Stratum X. At this stage there were no permanent structures and an absence of pottery, but burials of seven babies and young children attest to the presence of families arguing that this stage did, in fact, represent a settlement (*cf.* Winder 1991 : 43)

By Stratum IX, C-14 dated to between  $7570 \pm 150$  and  $7000 \pm 180$  BP, however, structures of hard fired bricks and stones were present. Pottery first appeared in this stratum, although in very small quantities, and continue to increase in each successive stratum throughout the period (Evans 1964 : 196). Evans also comments that "even at its first appearance, however, the pottery bears all the marks of a fully developed traditions of potting. Instead of the very simple vessels which mark the beginning of pottery at Catal Huyuk in Anatolia and Nessonus in Thessaly, we find wares with a variety of shapes and a number of special features... It therefore seems unlikely that we are dealing here with early experiments in pot making despite the early dates suggested by the C-14 samples". If the dating is correct this pottery represents a great advance on any such work at present known in the Aegean and Eastern Mediterranean. There is also no doubt that even at this early stage the material culture of Early Neolithic Crete is quite

distinct from that of the mainland (Branigan 1970 : 11) as it was to be later from the culture developed in the Cyclades.

The origin of the settler population of Crete is still not certain in spite of archaeological investigation and ceramic comparisons over a long period. Anatolia has been, and still is, the most likely candidate but the west-central Aegean has been suggested by Broodbank and Strasser (1991 : 237) who also point out that an Africo-Egyptian solution may be ruled out as the relevant domesticates are not attested there until substantially later (Hassan 1988 : 143, *cited* Broodbank and Strasser *ibid* : 237). The corrected radiocarbon dates for the Fayum are between *c.* 5100 and 4500 BC and for the Badarian, Amratian and Gerzian sites between *c.* 4100 and 3500 BC (Hassan 1984 : 64).

Although the colonisation of the other large Mediterranean islands Corsica, Sardinia and Cyprus was broadly contemporary with that of Crete, the Cyclades and other smaller southern islands among Crete's Aegean neighbours were not settled until some two millennia later in the Late Neolithic period (Cherry 1990 : 150-160) when the occupation of less advantageous zones is attested in many parts of later Neolithic Europe (Cherry 1981 : 59). On the southern mainland, the Peloponnese also attracted few settlers in the early period except at Franchthi and other coastal sites such as Lerna and Aletrypa together with a few inland sites.

In Crete, other than Knossos, only two Early Neolithic sites, Gerani Cave and Lera Cave have been identified with any certainty (Watrous 1994 : 700). While the settlement at Knossos grew from 0,25 hectares at the earliest stage to 5 hectares in the Late Neolithic period (Evans 1971, *cited* Watrous *ibid* : 700), other sites remained sparse until the Final Neolithic period in the late 5th Millennium BC when there appears to have been an increase of activity throughout the Aegean - a period of transition during which the material and perhaps economic balance of power began to shift from the north to the south. New settlement was beginning in the Peloponnese, the Cyclades and at many sites in Crete where influence from Chalcolithic Anatolia and the north east Aegean has been detected (Warren and Hankey 1989 : 13).

Phaistos was possibly a Late Neolithic site of some size. In two important respects its location is similar to that of Knossos lying on the Mesara Plain in one of the areas of high arable productivity today with a permanent source of water (Jarman *et al* 1982 : 142). Sites are also

recorded on the Akrotiri peninsula of Chania, in Sphakia in west Crete, open settlements and caves on the Mesara coast, on the central plain, in the Asterousia mountains and on Mount Ida. In the plain of Kavousi, in the Istron area and the island of Pseira coastal sites were occupied as well as caves and open sites on the plain of Lasithi and high in the Dikti mountains (Watrous 1994 : 700). Although many of these new sites could be interpreted as seasonal and complementary dwellings of a relatively small number of gardening agriculturists and pastoralists, together with the increase in size of the Knossos settlement, it may be inferred that an increase in population took place at this time.

Present knowledge of the environmental, demographic and technological background of Neolithic agriculture gives the impression of small farmers, dependent on tools of stone, bone, clay and wood working the land armed only with a hoe, mattock or digging stick - very arduous in the Aegean region. This meant that cultivation was restricted to a range of well-watered fertile soils that were probably better than at present and within walking distance of the settlement. Pulses and cereals, grown in similar quantities may have been grown in rotated fields. Sheep, goats, pigs, cattle and dogs were kept for meat, manure, skins and ritual purposes but in common with other rural societies may have been perceived as wealth in themselves. Meat in any form from the archaeological record of bones, appears to have been a supplementary and perhaps luxury food possibly allied to the requirements of leather or skins (Halstead 1981b : 320).

In the Late Neolithic the donkey, red deer, agrimi and rabbit or hare were added to the animal domesticates (Cherry 1990 : 163) and casual use began to be made of metal (Branigan 1974 : 97).

Van Andel and Runnels suggest that, in common with the Late Neolithic coastal sites on the southern mainland and the Peloponnese Late Neolithic sites on Crete are located "at the nodes of a network of island hopping routes that minimise distance between landfalls, particularly taking into account the lowered sea levels at that time, which could indicate the presence of embryonic trade routes that could have dated back into the Mesolithic" (1988 : 236). Indeed, travel and transport by sea in the mountainous regions of the Aegean would have been considerably easier than by land. Certainly the archaeological record of Final Neolithic Crete shows increased signs of widespread contacts with the Cyclades, the Peloponnese and elsewhere on the mainland and Cyprus. These signs of Cretan overseas contacts are part of a wider pattern

of "internationalism" that occurs throughout the Aegean and Near East at this time (Watrous 1994 : 701).

Van Andel and Runnels suggest that the sea-faring tradition that had been established for millennia now carried small quantities of value goods such as wool, obsidian, flint, millstones and perhaps salted or dried fish. The small permanent settlements contributed to the trade network while surviving on their own local produce including fish from the coastal sites, but depending greatly on exchange for those items they could not produce. This trade network is seen as a key element in the economic and social development of the Neolithic to Bronze Age transition in the Aegean and southern Greece which was later expanded to include the whole of the Mediterranean area (Van Andel and Runnels 1988 : 236)

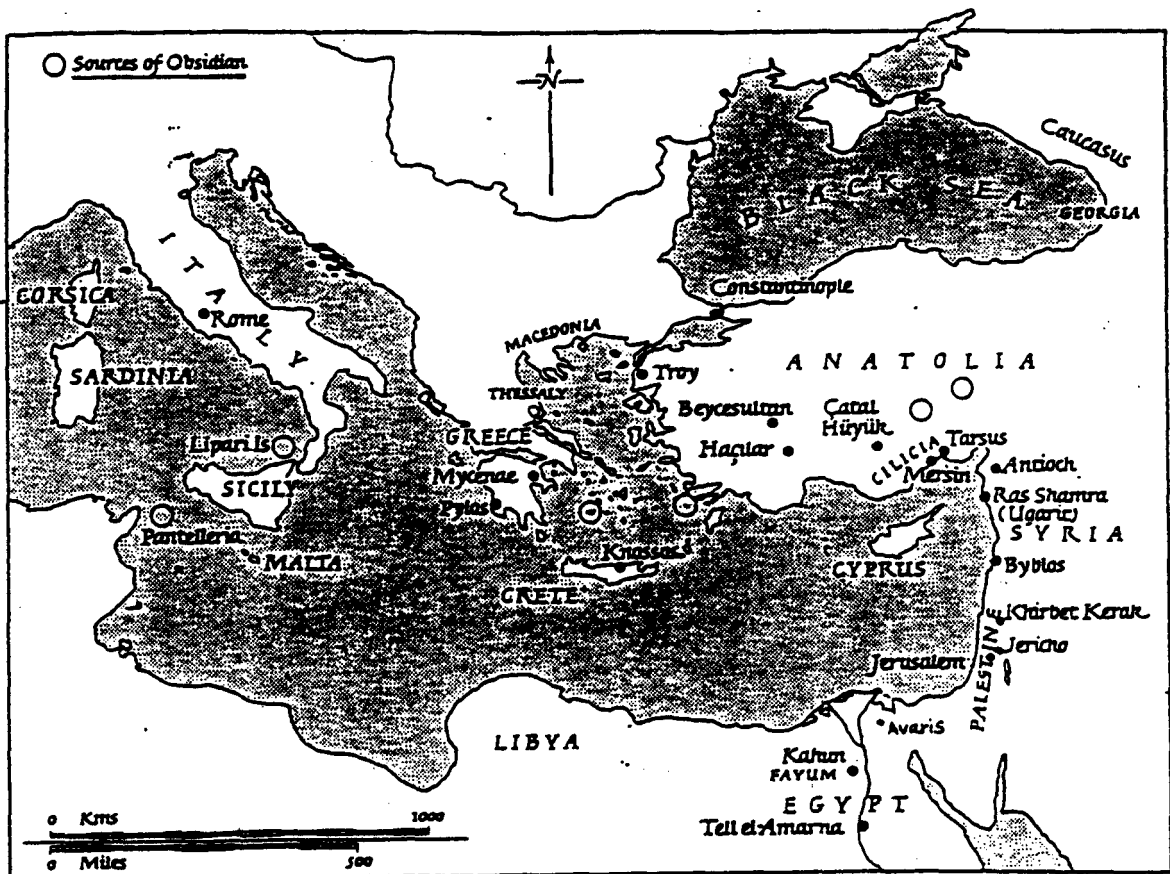
The Late Neolithic intensification of interaction in the Aegean, together with attendant movement of people, facilitated the transmission of innovative ideas particularly related to increased skill with and use of metals, increased exploitation of animal resources for power and products (Sherratt 1981 : 261-305) and improved ceramic technology. This resulted in a new subsistence strategy characterised by easier land transport and extension of workable land by ox-drawn cart, and/or primitive plough, greatly increased focus on pastoralism and the tentative introduction of orchard crops including the vine, nuts and fruits and later the olive. In Crete the limited extent of good arable land - less than 7% of the island (Jarman *et al* : 146) - has been seen as one reason for the development of both olive cultivation and the seasonal exploitation of sea-fishing and upland grazing areas. The subsequent dramatic rise in the number of settlements marks the transition to the Bronze Age and the Minoan period in Crete.

Van Andel and Runnels convincingly elaborate their hypothesis relating to the importance of further development of trade in the whole Mediterranean area, citing it as the reason for the concentration of growth in the south and the relative stagnation of northern Greece. The Early Minoan period saw an intensification of this process, which had begun in the Final Neolithic, and a shift of regional power to the south initially in Crete and the Cyclades and later spreading to the southern mainland. This led to the expansion of the established coastal sites and the foundation of new ones. The resulting accumulation of wealth in particular centres such as Knossos, which was blessed with both a key position with respect to trade and excellent agricultural resources, saw the rise of wealth-based social stratification. This led to the development of the 'palace

economies' with their remarkable architectural manifestations at Knossos, Mallia, Phaistos and Kato Zakro and their satellite settlements (Van Andel and Runnels 1988 : 233-247). This is dealt with more fully in Section 7.1.

It should be noted at this stage that the C-14 dating presented in the 1989 publication 'Aegean Bronze Age Chronology' by Warren and Hankey, brought together evidence for the relative and absolute dating for the area. The authors note that while changes in pottery styles correlated with Egyptian imports remain the basic framework for the chronology, this has been modified by C-14 dating and has required the revision of previous Minoan chronology. The Neolithic period ends and the Early Minoan I period begins at the earlier date of 3500 BC ending instead of beginning c. 2900 BC. Early Minoan II is dated to 2900 - 2300/2150 BC and the proto-palatial (Middle Minoan II) period to 1900 - 1700. If, however, the 'high' (c. 1625 BC) C-14 date instead of 1500 BC is accepted for the Thera explosion (Betancourt 1987 : 44-49; Manning 1990 : 91-100), the end of this period can be no later than 1800 BC. The evidence for the earlier date is not conclusive and Warren and Hankey do not accept it. Manning, however, as a result of the work presented at the Third International Congress on Thera and the Aegean World in 1989, concludes that it must be accepted as a working hypothesis.

(A Table of Minoan Chronology illustrating these figures together with the Egyptian correlation is given in Appendix 2.)



Map 2. The Eastern Mediterranean

Source: Hood 1971:13

### 2.3 Minoan Crete and its economic and cultural links

From the earliest stages of the archaeological exploration of prehistoric Crete, interconnections with its Aegean and Mediterranean neighbours have been the subject of great interest and speculation particularly relating to their possible influence on the development of Minoan culture. In the first half of the century many scholars attributed the rise of Minoan civilisation to foreign influences from Egypt and the Levant (Evans PM I 1922 : 4-20, 75-93, 122-126, 286-300; Xanthoudides 1924 : 128-132; Pendlebury 1939 : 35-170). So convinced was Pendlebury of the Egyptian connection that he postulated an Egyptian settlement in the Messara at the end of the Predynastic period: "It is they who may have started the Bronze Age in southern Crete" (1930 : 3). Egyptian artefacts discovered in Crete provided, at that time, the only dates which could be assigned to the Minoan periods strengthened, where possible, by reference to the Near East although scholars were well aware of the pitfalls of this practice (Pendlebury 1939 : xxvi).

The framework constructed in this way is still indispensable but the large number of Bronze Age excavations in the Aegean and the Near East in recent decades together with advances in the refinement of radiocarbon dating have rendered the Cretan Bronze Age chronology, to a great extent, independent of external evidence (Warren and Hankey 1989 : 3). The initial scepticism of classical scholars regarding the accuracy of Carbon-14 dating has largely been overcome so that emphasis has shifted away from the minutiae of stratigraphical correlations (Branigan: pers. comm.). Recent studies, in fact, have tended to view Cretan development generally as a local phenomenon at least up to the Early Minoan III/Middle Minoan I period. Branigan (1973 : 26) departing from his own conclusions of three years previously in 'Foundations of Palatial Crete' decided that there is no reliable or convincing evidence for any contact direct or otherwise between Early Bronze Age Crete and Old Kingdom Egypt and that Crete's first commercial contacts with the east Mediterranean were begun in Early Minoan III, but on a small scale with Cyprus and Syria; also that it was not until Middle Minoan I that trade began with the Levant and indirect contact with Egypt was established.

Interest in the subject remains strong, however, and Rehak points out in his review of some current literature on the subject (1997 : 399-401) that many new insights are being brought to bear including evidence for trade routes and probably nationalities of the traders and of the

goods involved including the evidence provided by the Cape Gelidonya and Ulu Burun shipwrecks. Most studies, however, represent activity late in the Bronze Age and it is more relevant to this enquiry to concentrate on earlier contacts that could have contributed to the development of Cretan technical, social and economic expertise including agricultural, pastoral, domestic and general organisational practices.

The "island hopping" trading activities in the Aegean discussed earlier were intensified from the Final Neolithic period probably inspired by accelerated metallurgical requirements and facilitated by better boats made possible by bronze tools. Metalworkers appear to have been dependent on Cycladic sources for their copper (as well as silver and probably gold (Dickinson 1994 : 237). Ideas gathered during travels probably introduced the wheel, the plough, animal traction and the cart at this time as Sherratt suggests that these, developed somewhere in northern Mesopotamia by the early fourth millennium, reached the Aegean about 3400 BC - marking the beginning of the Early Bronze Age as it did in Transcaucasia, Anatolia and the Balkans (1981 : 271). As pointed out by Pullen (1992 : 45), however, archaeological data to support these developments in the Early Bronze Age Aegean are few. The earliest representation of a plough from Crete and indeed from the Aegean proper, occurs in the Minoan hieroglyphic script where sign 27 is interpreted as a plough. A clay model of a cart was recovered from an unstratified deposit at Palaikastro and dated by decorative analogies to Middle Minoan Ia or possibly Early Minoan III (Bosanquet and Dawkins 1922 : 17). The cart has certain peculiarities in that the wheels are positioned under the cart rather in the manner of modern castors and there is no sign of any attachment for draught animals. Recent important earlier attestation of draught animals in the Aegean comes, however, from the excavation of the Early Bronze Age village on Tsoungiza Hill, west of the sanctuary of Nemea on the Greek mainland, where several terracotta figures of oxen have been recovered. One fairly well-preserved figurine has a yoke indicating that it was part of a pair of oxen used for some kind of draught (Pullen 1992 : 49).

Regular Cycladic/Cretan connections in Early Minoan I as evidenced by the amounts of imported obsidian and pottery continue into Early Minoan II when Cycladic metals, clay and stone vases, marble figurines and jewellery are found on almost every site particularly along the north coast. A possibly seasonal Minoan settlement was established on the island of Kythera, perhaps for trade with the mainland or fishing opportunities (Watrous 1994 : 711). Conversely, material from excavations of Early Minoan tombs at Ayia Photia, Siteia (Davaras 1971 : 392-97)

suggests that island people had settled in Crete and could have made a contribution to fishing skills as indicated by the finds of bronze fish hooks, and also possibly in boat building. The Early Minoan II clay model of a small rowing boat from Palaikastro (Bosanquet and Dawkins 1922 : 7) shows affinities with the sort of craft shown on some Cycladic so-called 'frying pan' vases (Tsountas 1899 : 91) with a high prow and extended stern. The significance and frequency of these early links with the Cyclades are, however, still far from clear (Cherry 1983 : 40).

There seems to have been little contact between Crete and areas outside the Aegean at this time. A Syrian mid-third millennium silver seal from Mochlos and a hippopotamus bone at Knossos are the only Near Eastern imports known (Watrous 1994 : 712) and a coherent pattern of contact with the Mediterranean seaboard in general can be first documented only just before the first palaces came into being i.e. Early Minoan III/Middle Minoan 1 (*cf.* Branigan 1973 quoted above). It is perhaps significant that the first seals showing boats with sails appear at this time (Cherry 1983 : 41).

Watrous has drawn attention to connections with contemporary events in the Near East. Several cities in Anatolia and Syria had been destroyed by fire in unrest at the end of the Early Bronze Age period among them being Kultepe, Tarsus, Ebla, Ugarit and Byblos causing the whole area to go into a recession c. 2250 BC (1994 : 734). Refugees from these conflicts could have settled on the north coast of Crete where pithos burials, a type characteristic of western Anatolia and rare in the Aegean appear at this time from Chania to Zakro. It is also interesting that cist graves, a Cycladic form of burial appear at Archanes, Mallia, Pseira, Sphoungaras and Zakro. The suggestion has been made that Cretan settlements grew in Middle Minoan IA partly as a result of immigration from western Anatolia and the Aegean islands which also show signs of unrest at this time (*ibid* : 728).

Levantine trade also began to revive at the end of this period and by 1950 BC had become very active with the establishment of Assyrian merchants in Anatolia (*ibid* : 734). Trade between Egypt and the Levant, which had ceased with the fall of the Old Kingdom, began again at the beginning of the XII Dynasty and Egyptian objects appeared regularly at Byblos and Ugarit. Some of these were passed on to Crete as Minoan trade activity increased dramatically both internally and externally (Branigan 1973 : 26). As trade with the Levant grew rapidly, so did the variety and quantity of small luxury goods that appeared in Crete, including Egyptian objects

(including examples looted from earlier tombs) or Egyptianising copies. They date no earlier than the XII Dynasty i.e. Late Middle Minoan IA (Watrous 1994 : 736). Branigan sees the evidence that the trade in Egyptian commodities was channelled through Syria as being fourfold in that the range of Egyptian items imported is limited, Egyptian influence in Crete is still difficult to detect, there is little Minoan material in Egypt and that some Minoan ideas are reflected in Syria but not in Egypt (1973 : 27).

The fact that the Minoans greatly admired Egyptian ceramic and metal work is, however, indicated in the number of copies which were made. Miniature stone and clay vessels imitating Egyptian funerary vessels are numerous in Middle Minoan IA cemeteries which also produce larnakes, the tub and chest forms of which were known in Old Kingdom Egypt but were new to the Aegean. Direct Near Eastern influence may be traced in technological features detectable in Minoan metalwork shortly after 2000 BC (Watrous 1994 : 736) but direct Egyptian contacts of any appreciable nature do not seem to have occurred until the Late Minoan period when they are attested by Egyptian sources (E and Y Sakellarakis 1984 : 198-199).

Watrous does, however, suggest far greater implications for the increased connections with the Near East. Dating from Middle Minoan I, these contacts antedated the construction of the first palaces and he questions whether the Near East, in fact, played a part in their establishment in spite of the fact that recent studies have emphasised the evidence within Crete (Watrous 1987 : 66). For instance, J Walter Graham in reviewing the architectural origin of the palaces, concluded that the derivation from or imitation of Near Eastern palaces, such as Beycesultan, Alalakh, or Mari, was at most superficial (Graham 1968 : 6, *cited* Warren 1987 : 49) and that "Cretan palaces contain so many features peculiar to themselves that it is clear that they were essentially designed and developed by native architects responding to local needs and conditions".

Cherry, however, pointed out that the fact that the palaces and a few Early Minoan sites share certain architectural features in no way explains the emergence of palaces or the palace system. All these sites, he says, "have in truth relatively little in common with the later palaces in terms of scale, planning, labour intensity of construction, ornateness or the separate provision for a range of functionally different activities beyond the household level" (1983 : 35). He emphasises the "simplicity, both in organisation and in technology of Cretan societies at the

beginning of the Early Minoan period. The scene, in short, is that of a landscape thinly populated with settlements at the 'later village farming stage'... (but)...a millennium or so later, certainly by the nineteenth century BC, everything is different... The archaeological record of the Old Palace period... provides reasonably satisfactory evidence for small-scale states in operation" (1983 : 33-34). He questions the usually accepted gradual evolutionary process by which this was achieved: "I feel it is equally possible to argue on the same basis for a *discontinuous* model of organisational change in pre-palatial and proto-palatial Crete. It would be a model in which the emergence of palatial civilisation is seen primarily as a 'quantum leap': a rapid set of linked changes leading to a social re-ordering during a relatively short EM III/MM I period" - the evolutionary development in preceding Early Minoan I and II periods having formed an economic and social basis for this to occur i.e. that there was a 'readiness' for these changes (1983 : 35-38).

Watrous agrees, stating that "the basic changes in Cretan society which the first palaces represent, seems to have taken place over a relatively short period of time. If we look at the material culture of Crete at the end of the third millennium BC, a number of radical changes are apparent: writing, monumental ashlar architecture, intensified trade in metals, peak sanctuaries, pithos and larnax burials, and specialised (wheelmade) pottery appear for the first time on the island". He goes on to ask directly: "How far was the Near East involved in these changes?" (1987 : 67) and does in fact find credible evidence of Near Eastern influence in all of them or the ideas behind them. His analysis of the probable syncretism of the attributes of Near Eastern, Egyptian and Minoan goddesses and religious practice is particularly interesting (*ibid* : 68).

Watrous concludes that the first palaces were established at a time of unusually close contact between the island and the near East and that since the novel features, identified above, which distinguish the palaces are found earlier in the Near East they are likely to be a foreign introduction or at least externally inspired and that they were assimilated (possibly) together with the institution of kingship (*ibid* : 70). Certainly the plan of the palace at Mari (Graham 1962 : Fig. 148, reproduced Warren 1987 : 51) bears a striking organisational resemblance to the Cretan palaces.

On the whole, however, it appears that experts generally see Late Bronze Age Crete as emanating primarily from an amalgam of indigenous cultural developments and strong northern connections from mainland Greece (Weinstein 1992 : 381). The northern influences came from

the involvement of the newly wealthy proto-Greek mainland centres of Mycenae, Tiryns and as a result of the immense growth of Minoan activity throughout the Aegean and into the Mediterranean. The Mycenaean culture developed increasingly close ties with the Minoan civilisation leading to a virtual "takeover" by the Mycenaean in the second palace period when they were rebuilt after the destruction of the first palaces around 1730 BC (if the 'new' chronology is accepted).

The XVIII Dynasty (1567 - 1320 BC), Late Minoan I-III connections between Egypt and Crete are well attested and indicate that at that time relationships were direct and well-established. Documentary and pictorial evidence from Egypt is fairly abundant (E and Y Sakellarakis: *op cit*) including the well-known frescoes at the tombs of User-Amon and Rehmire, viziers to Thothmes III (1504-1450 BC) and of Memhepereseneb priest of Amon at the same time which show traders bearing 'gifts' who were called 'Keftui' - now almost unanimously believed to be Cretans. Minoan or Minoanising frescoes have recently been discovered at Tel el Dab'a, identified with Avaris the capital of the Hyksos Intermediate rulers in Egypt. Previously published as relating to the Hyksos period (Bietak 1995a : 19-28), these frescoes have now been attributed to the early XVIII Dynasty (Bietak 1995b).

Although the evidence for Egypto-Cretan relationships during this time is indicative of lively direct exchange of goods and ideas, the contacts are apparently too late to be developmental or fundamental in nature. Possibly the most compelling influence is to be found in art and the subjects, organisation and conventions of the paintings of frescoes, pottery and larnakes (Watrous 1991 : 285-307). Since Cretan art is almost always associated with ritual or religious activity some, but not fundamental, influence may possibly be detected in these areas.

To conclude this section, although it is only marginally relevant to this study, some mention must be made of the radical model for the development of Greek civilisation by Martin Bernal in his (up to the present) two volume work 'Black Athena: The Afro-Asiatic Origins of Classical Civilisation' (1987, 1991), if only because of the substantial literature, mostly hostile, it has generated, which is a measure of its importance as perceived by the academic world. This ambitious and wide-ranging work reflects the author's strong political and social views. Bernal believes that the ancient Egyptians played a decisive role in the development of Cretan and subsequently, Greek civilisation with the Semitic Near East a close second - in a sense reviving

the ideas of Evans and Pendlebury and indeed the Hellenistic perception - adding a mass of further citations, including myths and legends, and many of his own fabrications.

Bernal accuses modern European and American scholars of rejecting these ideas because of racial prejudice against black Africans and Semites. His writing is that of a very widely read man who manipulates and distorts his material to serve his ends (Bernal 1990 : 111-127). His critics point out that while some of his theories may well prove to be right (particularly relating to Near Eastern influences), they are so intertwined with misused primary sources and nonsense relating to Egyptian and Hyksos Aegean invasions together with dubious chronology and linguistic links, that the work is unacceptable (Weinstein 1992 : 382). 'Black Athena' is particularly dangerous to the non-specialist, as it is entertaining reading, appears so plausible and is obviously believed by the author. His claims have received censure from a wide range of respected scholars particularly in 'Black Athena Revisited' (1996), edited by Lefkowitz and Rogers, as well as Muhly (1990), Lefkowitz, (1996 'Not out of Africa') and Weinstein (Review of Black Athena, Vol. II, 1992). All are agreed that, aside from the faulty scholarship, Bernal's avowed attempt to "give" people of black African descent a "history" by depicting the ancient Egyptians as black i.e. negroid, is exploitative of emerging black aspirations and, in feeding them untruths, denies them their own true history.

### **3. THE MEDITERRANEAN DIET AND ITS SUGGESTED NUTRITIONAL AND HEALTH BENEFITS**

#### **3.1 Cereals, olive oil and fish as components of the Mediterranean diet**

There is a large, technically complex and at times confusing literature on the health benefits of the 'Mediterranean diet'. A recent computer search at the University of Cape Town, for information on the traditional diet of the Mediterranean area rapidly produced over three hundred references.

The introduction of the term 'Mediterranean Diet' is usually credited to Ancel Keys, an American physiologist whose research was primarily directed towards establishing how the eating habits and dietary patterns of the Mediterranean area, characterised by a high cereal content, abundant olive oil and fish, related to the occurrence or absence of cardiovascular disease. In 1951 Keys initiated his international Seven Countries Study which examined the serum lipid levels of men in rural areas of Yugoslavia, Finland, the Netherlands, Greece, the United States of America and Japan. Keys' analyses showed a notably low incidence of cardiovascular pathology in the Mediterranean and Aegean regions. Blood serum cholesterol levels (typically raised in patients at risk for cardiovascular problems) were notably lower when compared with such countries as Finland and the United States of America. Keys suggested that this could be explained partly by the differences in the types of fats in the dietary intake of the various populations (Keys *et al* 1957, 1965; Keys 1970).

Keys (1970 : 1-211) has been criticised by a statistician for a possible selection effect in his research. Wood (1981 : 131-135) suggests the 21 member countries of the Organisation for Economic Co-operation and Development that maintained statistics of food consumption and deaths fall into two distinct groups, one of 15 countries and the other of 6. Statistically fewer than 1% of all possible drawings of 7 countries from the group of 15 gave a significant correlation. If one or more of the grouping of 6 countries was included the percentage correlation increases. Keys' study of seven countries included four from the group of 6 and three from the 15. Wood suggests that the probability of obtaining a significant positive correlation between diet and heart disease was 63,4% (1981 : 134).

In discussing the Mediterranean diet, however, care must be taken not to see it as a homogeneous model since the region is made up of many different populations each with its own varied dietary traditions. In a study using the Food Balance Sheets published by the United Nations Food and Agriculture Organisation, Rome (1987) covering the food intake of fourteen countries in the area, i.e. Greece, Italy, France, Portugal, Spain, Malta, Israel, Libya, Algeria, Tunisia, Turkey, Egypt, Morocco and Yugoslavia, it was, however, established that there is a common nutritional pattern for all Mediterranean countries which could be defined as 'Mediterranean Diet'. An investigation was undertaken into how far this diet corresponds to the current recommendations for the prevention of coronary heart disease (Giacco and Riccardi 1991 : 5), compared with figures for the United States from the same source, chosen as an example of a highly industrialised country at high risk for cardiovascular disease.

The average consumption of eggs, milk and dairy products was lower in all Mediterranean countries (62-430 grams/day) compared to the United States (505 grams/day) typically associated with a low consumption of meat. An interesting result concerned the high intake of cereals in the Mediterranean countries from which they derive 30-60% of their daily caloric intake as opposed to the United States where the average is only 19%, also a higher intake of legumes rich in fibre and complex carbohydrates. A very important characteristic was a high, although variable, consumption of olive oil as a substitute for animal fat (see Figure 8). On Crete the traditional diet of whole grain bread, pulses, fruit, wild greens and herbs together with abundant olive oil were the basic Cretan foods for forty centuries (Allbaugh 1953 : 100) until about thirty years ago. Studies in Italy, particularly the European Atomic Energy Community (EURATOM) begun in 1960 (Cresta *et al* 1969 cited Cominacini *et al* 1991: 199) confirm that the Mediterranean diet is characterised by being:

- (1) low in animal fats and consequently in cholesterol
- (2) low in animal protein
- (3) rich in complex carbohydrates
- (4) rich in leguminous and vegetable fibre

FIGURE 8  
Consumption of olive oil in the Mediterranean countries and the United States of America  
(Source: Giacco and Riccardi 1991 : 6)

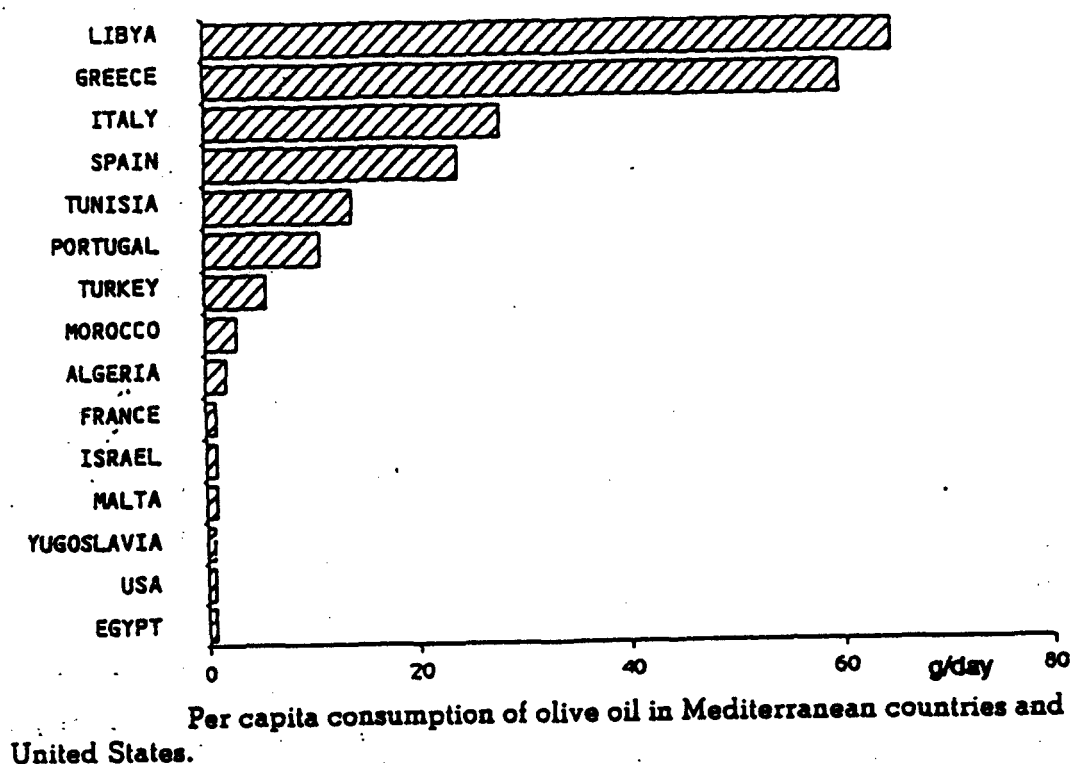


Figure 8 indicates that olive oil consumption in Greece remains at the traditional high level (approximately 60 grams/day) together with Crete and the Cyclades, being only second to Libya in world consumption. Egypt, which has never been an important olive growing region, has the lowest consumption of the oil in the Mediterranean (Giacco and Riccardi 1991 : 6). This lack of olive oil in Egypt probably extends back to the Bronze Age when, in the absence of other forms of oil, it would have been a serious disadvantage. It could have been imported from the Levant and also from Crete in the Late Bronze Age. Table 1 below provides a comparison of fat intake for modern Cretans and westernised industrialised Americans.

TABLE 1  
Comparative fat intake (grams/day) of Cretans and Americans  
(Pique 1988 : 101)

Dietary fatty acids	Cretans (1960)	Americans (1983)
Saturated	28	58
Mono-unsaturated	86	66

Table 1 shows that intake of mono-unsaturated (mainly vegetable) fats on Crete was some 30% higher than that of Americans while consumption of saturated (mainly animal) fats was 52% lower. The Cretan figures represent the traditional island diet since the shift to a more westernised diet in the major centres only occurred after 1960 (Corondialis, Ioannidis and Aravanis 1980, *cited* Pique 1988 : 102). It is, however, noteworthy that the traditional diet is essentially retained in the country and mountain villages of eastern Crete.

Table 2 (below) provides quantified data on the different fat and carbohydrate contents of diets in some Mediterranean, European and Far Eastern countries. Death rates from coronary heart attacks (myocardial infarctions) per 10000 people in 15 years are given in the last column. The table confirms that the diet of the Mediterranean and southern European region is characterised by a low saturated fat intake and a relatively high consumption of carbohydrates and a lower rate of cardiovascular disease. (It should be noted that cereals are complemented by potatoes in the carbohydrate fraction of the modern diet in the Mediterranean countries especially in Greece. These would not have been available in the Bronze Age.)

TABLE 2

Average estimated consumption of some nutrients and death rates from coronary heart disease  
(Keys *et al* 1986 : 903-915, *cited* by A Menotti 1991 : 238, Table 12-1)

Country	Total fat	Saturated fit (S-fit)	Mono- unsaturated fit (M-fit)	Poly- unsaturated fit (P-fit)	Carbo- hydrates	Ratio of P-fit to S-fit	Ratio of M-fit to S-fit	Coronary heart disease (per 10000 in 15 years)
(per cent of total calories)								
United States	38,0	16,2	16,2	4,8	43,7	0,30	1,00	773
Eastern Finland	38,5	23,7	11,9	2,9	53,9	0,12	0,50	1202
Western Finland	34,3	19,4	11,3	3,0	50,8	0,85	0,58	741
The Netherlands	38,0	20,2	12,5	5,4	45,3	0,27	0,62	636
Italy (a)	27,0	8,9	11,4	3,2	50,2	0,36	1,28	424
Italy (b)	24,5	9,6	11,6	3,3	54,3	0,34	1,21	447
Italy (c)	27,4	7,6	17,1	2,7	51,2	0,36	2,25	515
Yugoslavia (a)	31,9	13,6	13,3	3,4	49,8	0,25	0,98	389
Yugoslavia (b)	32,6	9,7	20,1	3,1	50,0	0,32	2,07	297
Crete	36,1	7,7	25,8	2,5	49,4	0,33	3,35	38
Corfu	33,0	6,4	18,3	3,5	47,6	0,54	2,86	202
Japan (a)	9,0	2,9	2,9	2,9	73,3	1,00	1,00	144
Japan (b)	9,0	2,9	2,9	2,9	73,6	1,00	1,00	127

Note: Men with major cardiovascular disease at entry are excluded, as well as those who died from accidents.  
Proportion of calories on total calories including alcohol.

The above table is particularly relevant to the traditional diet consumed on Crete since it shows that although the total fat and carbohydrate intake is roughly similar to the other countries, the ratio of saturated (mainly animal) fats (7,7%) to unsaturated (mainly vegetable and fish) fats (28,3%) was low. The latter figure was composed of 25,8% mono-unsaturated (mainly vegetable) fats and 2,5% polyunsaturated (mainly vegetables and fish) fats comparable to that of Corfu only. Both islands had low rates of cardiovascular disease compared with the northern countries, but it is difficult to accept that the startlingly low rate in Crete is attributable only to diet and further investigation to identify other factors could be enlightening.

Supplementation by fish of this high cereal, high olive oil diet, as the evidence to be presented for Bronze Age fishing shows, occurred particularly on Crete and the Cycladic islands. Many of the fish caught were particularly rich in nutritionally important fats as later classification and analysis will show.

Two medical studies, one in Finland (Ehnholm *et al* 1982) and the other in Italy (Ferro-Luzzi *et al* 1984), provide support for the health benefits of the high carbohydrate, low saturated fat Mediterranean diet. In the Finnish research a group of middle aged volunteers was invited to replace their usual diet rich in saturated fatty acids by the traditional Mediterranean diet for a period of six weeks. The results showed that the volunteers' plasma cholesterol levels had decreased significantly. At the end of the trial period and on resumption of their normal diet, their cholesterol returned to its previous levels. Complementary to this study was the second trial carried out in Cilento, southern Italy, where the traditional Mediterranean diet was replaced by a typical northern European diet resulting in raised cholesterol levels which returned to their previously low levels when the participants returned to their usual high cereal, olive oil and low saturated fat diet. These two studies, among many, confirm the relationship between dietary patterns and blood serum lipid levels.

A randomised controlled dietary trial of 2033 patients who had recently recovered from myocardial infarction resulting from ischaemic heart disease (IHD) is reported from south Wales (Burr *et al* 1989 : 757-761, Burr 1989 : 291-316). The patients were divided into three groups each allocated to receive or not receive dietary advice on the following three factors:

- (a) a modification in fat intake - reduction to 30% of the total energy intake and to increase the ratio of polyunsaturates to saturated.

- (b) an increase in fatty fish intake - the consumption of at least two portions of fatty fish per week. (Mean EPA intake was calculated at 2,3 grams/week corresponding to about 290 grams of fish.
- (c) an increase in cereal fibre intake to 18 grams/day.

At the end of a two year period, the overall mortality of the group given the fish diet was 9,3%. That of the reduced fat group was 12,8% and there was no evidence of any benefit from the daily cereal fibre intake (Burr *et al* 1989 : 761). The results suggest that fatty fish reduces the risk of death from later arrhythmias in high-risk patients. Further research indicates that this is likely to be the result of profound effects of EPA and DHA on the clotting mechanisms of the blood together with the probability that these fatty acids reduce the tendency for atheromatous plaque to develop in arterial walls (Burr 1989 : 296-310). Ackman (pers. comm.) points out that the success of this trial inspired the United Kingdom Department of Health to recommend that the population of the United Kingdom eat oily fish twice a week (Nutritional Aspects of Cardiovascular disease 1994, No 46 : 4).

Two further publications describe the use of an adaptation of the traditional Cretan diet in secondary prevention of coronary heart disease (de Lorgeril *et al* 1994 : 1454-1459; Renaud *et al* 1995 : 1360S-1367S). Patients assigned to the experimental group consumed less lipids, saturated fat, cholesterol and linoleic acid, but more oleic and alpha-linolenic acids. In practical terms the patients were advised to eat: more bread, more vegetables and legumes, more fish, less meat (replaced by poultry), no day without fruit, no more butter and cream (to be replaced by a rapeseed oil-based margarine).

The two publications report that after a follow-up of 27 months, recurrent cardiac pathology and deaths were reduced by about 70% in the group consuming the modified traditional Cretan diet (Renaud *et al* 1995 : 1360S; de Lorgeril *et al* 1994 : 1454). The protective effects are attributed to an increase in *n*-3 fatty acids and oleic acid, and a decrease in linoleic acid that resulted from higher intakes of linolenic and oleic acids.

In a letter to the Lancet (1994 : 893-894), Rice questions whether the reduction in cardiac deaths can be attributed to the alpha-linolenic acid-rich diet. He points out that the data of de Lorgeril *et al* (1994 : 1454-1459) and Renaud *et al* (1995 : 1360S-1367S) includes an 18% rise in fish intake that may have included oil-rich varieties. This would have contributed to the 35% rise in plasma eicosapentaenoic acid (C20:5*n*-3) in the experimental group of patients.

Furthermore, the rapeseed oil margarine, used as a source of alpha-linolenic acid, is not converted effectively to the desirable docosahexaenoic acid (C22:6n-3). Rice suggests that encouraging patients to eat more oil-rich fish is probably a more realistic approach to preventing coronary heart disease.

In the meantime Ackman has been involved in research to determine whether there could be undesirable effects of over-consumption of fish oils (Ackman 1988 : 151-155) and Gussow has raised the question as to whether it is environmentally responsible to recommend the Mediterranean diet to populations outside the regions where it occurs naturally (1995 : 1383S-1389S). She suggests that a broader definition of the diet might be possible and that research should be undertaken to identify suitable local alternative substitutes for the Mediterranean products.

At the age of 93 and a living advertisement for his theories, Ancel Keys still (1997) has strong opinions on the subject and in a taped interview with an American food magazine, he rejects faddish diets that have resulted from his publications. Low fat diets simply lower the valuable calorie intake - it is the saturated fats that must be reduced; he also rejects similarly cutting down on the percentage of carbohydrates and increasing protein. He also states that there is no evidence that high cholesterol in foods such as eggs, raises the blood cholesterol level - here again it is the saturated fats that are the problem. Along with other experts (*cf.* Fogerty 1989 : 36-37), however, he cautions that within the last decade the simplistic proposed relationship between dietary fatty acids and heart disease have been shown to be more complex in that all components of cholesterol are not harmful, not all saturated fats may have a deleterious effect, and the balance between the dietary intake of omega-3 and omega-6 polyunsaturated fatty acids has to be established.

Early work on the lipid hypothesis tended to concentrate on the effects of the saturates and polyunsaturates on serum cholesterol levels. More recently, referring back to the work of Keys, there has been revived interest in mono-unsaturates particularly the oleic acid present in olive oil and other high oleic oils. Also, the effect on human health of the essential polyunsaturates derived from fish oil has received increasing attention. The effects of dietary fatty acids are also being studied in relation to other diseases such as cancer and arthritis besides coronary heart disease and atherosclerosis (Fogerty 1989 : 43).

As Leaf has pointed out the changes in total, saturated and omega fatty acids occurred as a result of the Neolithic changeover from hunter-gathering to a farming economy. At about 10000 years ago, this came late in human evolution and it was one for which the genetic makeup was not prepared (1993 : 2). In most parts of the Old World, it resulted in a high cereal diet with an increase in saturated fats, dairy products and the meat of fattened cattle.

For environmental, climatic and demographic reasons, the nutritional pattern of Bronze Age Crete differed from that of its northern counterparts. Archaeological, botanical and Linear B evidence suggests that from the second millennium BC reliance was placed on the use of olive oil, high in mono-unsaturated fatty acids, for culinary purposes (Renfrew 1972 : 304; Runnels and Hansen 1986 : 299-398; Hansen 1988 : 44-47). This use of olive oil was almost certainly associated with a reduction in consumption of animal fats.

There is evidence for increased emphasis on wool rather than meat production at this time (Halstead 1981b : 328-329). Faunal remains of caprids and finds of spindle whorls at Early Minoan I Debla in west Crete (Warren and Tzedhakis 1974 : 262-263) and Early Minoan II Myrtos in east Crete (Warren 1972 : 262-63) may indicate that sheep were beginning to be reared for wool. The presence of approximately equal numbers of mature male and female sheep remains on archaeological sites may support this hypothesis since males produce more wool than females (Halstead 1981 : 328-329). Halstead cautions, however, that study of the proportions of bones recovered as well as sex and age compositions of herds is essential when reconstructing farming strategies. Recovery, preservation and skill in identification of animal bones, however, varies on archaeological sites.

If, however, the Minoans valued their herds too highly to slaughter animals often, it could mean that consumption of saturated fats on Bronze Age Crete was relatively low and that olive oil was used as a substitute for animal fat. As an island society with a close association with the sea, fish and other marine resources were surely an important supplementary part of the diet, as will be discussed later.

At this stage it is necessary to provide a short note on the chemistry and chemical nomenclature of fats and oils in order to clarify the data which will be presented in the following sections, particularly relating to olives and fish.

### 3.2 A note on the chemistry of dietary fats

(This section is to a great extent indebted to Fogerty 1989 : 36-45).

The term 'lipid' is used by organic chemists to describe what the layman knows as 'fat' or 'oil', depending on whether the substance is solid or liquid in form. Triacylglycerols (TAG) account for about 90% of lipid intake with phospholipids, glycolipids and cholesterol making up the balance. Since TAG and phospholipids are composed almost entirely of what are known as 'fatty acids', their types and amounts are relevant to nutrition and health. The fatty acids are long-chain mono-carboxylic acids.

(a) **Fatty acids:** comprise a methyl group ( $\text{CH}_3$ -) at one end, a chain of methylene units ( $-\text{CH}_2$ - groups) and a carboxyl group ( $-\text{COOH}$ ) at the other end. They usually contain an even number of carbon atoms and the term 'fatty acid' is applied to those containing six or more carbon atoms. Dietary fatty acids usually contain between 6 and 22. **Saturated fatty acids** have only a single chemical bond between the carbon atoms, i.e. no double bonds. The presence of double bonds in the chain characterises **unsaturated fatty acids** (see also below).

(b) **Nomenclature:** The terms which describe precisely the chemical structure of a fatty acid can be confusing for a non-specialist. For example '*n*-hexadecanoic acid' indicates a straight chain (*n*-), sixteen-carbon (hexadecan-), carboxylic (-oic), acid (chemical formula  $\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$ ). Similarly, the term octadecanoic acid indicates the presence of 18 carbon atoms (chemical formula  $\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$ ). This is further complicated by the use of common names for the acids for example: palmitic acid for hexadecanoic acid and stearic acid for octadecanoic acid.

(c) **Shorthand:** Because the chemical nomenclature is complicated, a shorthand notation has been developed which indicates the number of carbon atoms followed by the number of double bonds (see below). Thus *n*-hexadecanoic (palmitic) acid will be written 16:0 (sixteen carbons, no double bonds) and stearic acid is 18:0. These are the most abundant saturated fatty acids in the diet.

(d) **Unsaturated fatty acids:** These can be of the monounsaturated or poly-unsaturated type and are characterised by the presence of double bonds.

- (i) **Mono-unsaturated** fatty acids contain one double bond in the carbon chain, e.g. oleic acid (18:1). However, because the position of this bond between any two methylene units on the chain determines the type of fatty acid and because the geometric isomer may be of the *cis*- or *trans*- type the exact description of oleic acid would be *cis*-9-octadecenoic acid signifying that the double bond is of the *cis*- type, lying between carbon atoms 9 and 10 (numbered from the end of the chain), octadec- (18 carbon atoms), -en (double bond) and -oic (carboxylic acid). Oleic and palmitoleic (16:1) are the most common dietary mono-unsaturates. Most mono-unsaturated fatty acids are of the *cis*- type, *trans*- types only occurring in red meat, dairy products and margarines containing hydrogenated vegetable or marine oils.
- (ii) **Polyunsaturated** fatty acids (PUFA) contain two e.g. linoleic acid (18:2) or more e.g.  $\alpha$ -linolenic (18:3) double bonds. The number, positions and configuration of each bond, however, determines the type of fatty acid with resulting great complication. Problems with unwieldy correct names for PUFA in food chemistry have been overcome largely because the natural PUFA fall mostly in two series depending whether they are derived from linoleic acid or  $\alpha$ -linolenic acid. Reversing previous procedure and numbering the double bond from the last or 'omega' carbon (methyl group), it became obvious that linoleic acid and all its derivatives have the double bond nearest the methyl group in the omega-6 position and that  $\alpha$ -linolenic acid and all its derivatives have this bond in the omega-3 position. Recently the variants *n*-6 and *n*-3 have been used together with the shorthand thus 18:2*n*-6 indicates linoleic acid and 18:3*n*-3 indicates  $\alpha$ -linolenic acid. It should also be noted that these fatty acids are the only two which cannot be synthesised by the body and they are therefore termed 'essential'.

The origin of the nomenclature of the important complex polyunsaturated fatty acid in fish oils can thus be tracked: eicosapentaenoic acid (EPA) 20:5*n*-3 i.e. twenty carbons, five double bonds derived from  $\alpha$ -linolenic acid should be noted; also docosahexaenoic acid (DHA) 22:6*n*-3 i.e. twenty-two carbons, six double bonds also derived from  $\alpha$ -linolenic acid.

#### 4. CEREALS IN MINOAN CRETE

The earliest farmers on Crete arrived about 6000 BC and brought with them a range of crops very similar to those found in the Near East with wheat being the main cereal crop (Jarman *et al.* 1982 : 147). Palaeobotanical evidence for the cultivation of emmer wheat is also found at about the same time in the north of Greece at Ghediki, Sesklo, Argissa, Archilleion in Thessaly and Nea Nikomedeia in Macedonia (Jane Renfrew 1973 : 26, Map 2). The range of cereal species included single-grained einkorn, hulled and two-row barley, hulled six-row barley, possibly broom corn millet, oats, peas, lentils and vetch acorns. To limit the risk of crop failures different species of cereals such as rye were cultivated along with emmer, millet and oats (Lintas and Mariani-Constantini 1991 : 59). Mixed crops are still a feature of subsistence agriculture in the Cycladic islands and Jane Renfrew writes that in 1965 she saw a field of *Triticum dicoccum* (emmer wheat) growing alongside barley and oats, mixed with peas and beans. Comparison of the Linear B records with the botanical evidence however suggests specialisation with wheat as the main cereal.

With regard to the species of wheat cultivated on Minoan Crete it is pointed out that in addition to two wild strains, fourteen domesticated cultivars of wheat are recognised. These are divided into three groups on the basis of their chromosomes and can be further sub-divided into those species whose spikelets remain intact after threshing (i.e. hulled grain), and those whose grains thresh free from the glumes (naked grain). However according to Jane Renfrew the system of nomenclature used for wheat species remains a fertile field for argument amongst taxonomists.

The earliest archaeobotanical evidence for the cultivation of wheat on Crete comes from Stratum X of the Knossos Neolithic. This stratum consisted of a relatively thin deposit of habitation debris which lay immediately above bedrock in Area AC. The average depth was about 20 cm but it attained a maximum thickness of 40 cm in places. Just to the east of the central part of AC a roughly oval patch of earth was found which contained a large quantity of carbonised grains. The grain included naked hexaploid wheat (?) *Triticum aestivum* L (bread wheat), emmer *Triticum dicoccum* and barley of the genus *Hordeum*. An oak stake associated with the area where the grain was found provided a C-14 sample which was dated by the British Museum Radiocarbon Laboratory to 6100 ± 180 BC (BM 124).

In the absence of permanent structures John Evans (1964 : 142) suggested that the stratum where the grain was found could represent the remains of a temporary campsite set up on the virgin hilltop at Knossos by the first arrivals. Evans' theory is supported by an absence of pottery and small finds. Winder (1991 : 43) in his reassessment of the Knossos Neolithic disputes the idea of a temporary campsite, finds the evidence inconclusive and recommends that the excavation material be re-examined. The cereal remains recovered indicate however that these earliest arrivals on Crete had a prior knowledge of wheat and barley cultivation and brought seed with them. Origins suggested for this seed include Anatolia, Cilicia or Syria-Palestine (Hood 1971 : 28). The botanical remains recovered by John Evans were examined by the late Dr Helbaek who regrettably only published a preliminary report on the material. In view of the importance of the early date for these samples of bread wheat on Crete (c. 6000 BC) and their relevance to the origins of agriculture in the Aegean, Winder suggests that an up-to-date comprehensive report on these cereal remains is an important priority.

In view of the nutritional importance of cereal in the Mediterranean diet it is necessary to point out that the main taxation records from the palaces provide no evidence for specialisation in particular agricultural products (Halstead 1992 : 108). Halstead argues that cereal production in the Late Bronze Age in southern Greece was specialised but only in the sense that the palaces concentrated on part of the range of agricultural resources exploited by the non-palatial sector. Wool, olives and cereals are amongst the commodities identified from archaeological and archival evidence. Halstead suggests that the simplest and safest conclusion is that the Late Bronze Age palaces sponsored production of just one wheat species and that other crops such as barley and pulses were produced independently of palatial control.

Table 3 contains a list of Bronze Age sites on Crete that have yielded archaeobotanical evidence for wheat, barley and pulse crops.

TABLE 3

Archaeobotanical evidence for cereal and pulse crops on Crete in the Bronze Age  
(Based on Halstead 1992 : 108)

Provenance	Cereals	Pulses
Crete		
Ayia Triadha villa, Magazine 5 Room 39	Wheat	Lentil Chickpea, pea
Ayia Triadha house	Wheat	Grass pea Pea
Gournia town		Pea, bean
Knossos palace, magazine 3	?Barley Corn	
W. Temple Repository	Wheat	Bean
Lapidary's Workshop		
Knossos Caravanserai	?Barley	
Unexplored Mansion	Bread wheat, emmer, hulled barley	Grass pea, Celtic bean, <i>Vicia Lathyrus</i> sp.
Mallia palace, E. magazines	Wheat	Lentil Lentil
Room V <sub>2</sub>		Chickpea
Room XXV <sub>3</sub>		Bitter vetch
Myrtos Pyrgos	Hulled Barley	
Myrtos, Fournou Korifi	Wheat barley	
Nirou Khani		Celtic bean, vetch
Palaikastro town, Room 23	(?Bread) wheat	Pea, wild pea
Room 38		Pea
?	Barley	

## References to Table 3:

- Ayia Triadha:** Follieri M. 1979-1980. Provviste alimentari vegetali in una casa minoica ad Hagia Triadha (Creta). *AS Atene* 57-58 (NS 41-42), (pr. 1986) 165-172, *eadem* Cibi carbonizzati in livelli tardo minoica a Canca (Creta occidentale). *SMEA* 23, 1982 : 137-141
- Gournia:** Vickery KF. 1936. Food in early Greece (Illinois studies in social sciences, 20.3) 19f.
- Knossos:** Magazine 3-B. Haussoullier 1880. Vases peints archaïques découverts à Knossos BCH 4 124-127. esp 127. Evans A. 1921-35, Palace of Minos IV, 621f. W. Temple Repository, P of M I; Lapidarys Workshop. Evans, A. 1900-1901 The palace of Knossos, *Annual of the British School at Athens* 7 : 1-120, esp. 20f. Evans A. P of M II Caravanserai, 105. Jones G. 1984. The Minoan Unexplored Mansion at Knossos (British School at Athens Supplementary Volume 17), MR Popham London 1984, 303-306. Sarpaki A and Jones G. 1990. Ancient and modern cultivation of *Lathyrus clymenum*. *British School at Athens* 85 : 363-368. Evans A, P of M IV, 622.
- Mallia:** East magazines - Chapouthier F and Charbonneaux J. 1928, Fouilles exécutées à Mallia 1 (Et Crét I), Paris 38. Room V.2 *op cit.* 18. Room XXV3. Chapouthier F and Joly R. 1936. Fouilles exécutées à Mallia 2 (Et Crét 4), Paris, pl. 8(2): Chapouthier F and Demargne P. 1942. Fouilles exécutées à Mallia 3 (Et Crét 6), Paris, 14.
- Myrtos Pyrgos:** Cadogan G. 1977-1978. Pyrgos. Crete 1970-7. *Archaeological Reports* 24, 1977-1978 : 70-84, esp. 83.
- Myrtos, Fournou Korifi:** Warren P. 1972. Myrtos. An Early Bronze Age Settlement in Crete 35 : 256, 295, 317.
- Nirou Khani:** Vickery KF. 1936. Food in early Greece (Illinois studies in the social sciences 20, 3). Illinois. 19f.
- Palaikastro:** Bosanquet RC. 1901-1902, Excavations at Palaikastro I, Room 23, *Annual of the British School at Athens* 8 : 286-316, esp. 316. Dawkins M, 1902-1903, Excavations at Palaikastro 2, Room 38, *Annual of the British School at Athens* 9 : 290-328, esp. 292. Bosanquet RC 1902-1903, Excavations at Palaikastro 2, Room 38, *Annual of the British School at Athens* 9 : 274-289, esp. 280.

The archaeobotanical evidence contained in Table 3 though limited does provide confirmation for wheat and barley that is referred to in the Linear B tablets from Knossos (Ventris and Chadwick 1973; Baumbach 1977 : 10). The botanical and textual evidence taken together indicate that the cultivation and harvesting of grain was a longstanding traditional form of agriculture on Crete. At Knossos the practice extended back to the late seventh or early sixth millennium BC. By the later Minoan period cereal cultivation was well established and control and redistribution of the harvests had largely passed to the major palaces.

The specialised nature of the grain harvests handled by the palace bureaucracies complemented the more diversified and mixed crops noted by Halstead (1992 : 115) and Jane Renfrew (1973 : 28). The assumption is that whereas the intention of the palaces was to produce and redistribute a grain surplus, the rural Cretan farmers and others on the Cycladic islands cultivated a wider range of cereals and other agricultural products, primarily to ensure against the failure of a single species crop (Halstead 1981a : 195).

Evidence for an early well developed, diversified agricultural regime was found at Myrtos in eastern Crete where wheat and barley were harvested, olives cultivated and viticulture practised (Warren 1972 : 255-256). Myrtos situated on the coast is dated to Early Minoan II c. 2200 BC and had an estimated population of some 100-120 (*ibid* 267). An alternative estimate is 25-30 (Whitelaw 1984 : 339). The settlement provides a model for the pattern of agricultural production that was eventually to form the economic basis of the later palatial civilisation. Evidence for cereal production was found at Myrtos in Room 20 (the Room of the Raised Hearth) in the form of wheat and barley impressions on pottery fabric. One piece of pottery (number 231), a fragment of a clay stand has impressions of wheat and barley on its surface and throughout the fabric (Appendix V, Pl. 84A). Additional to this evidence for Early Minoan cultivation of cereals is a specimen of mud plaster (P629) found in Room 82. Amongst the impressions parts of the lemmas and glumes of hulled barley can be distinguished.

Other archaeological evidence for the cultivation and use of cereals at Myrtos is a stone quern for grinding corn found in Room 81. Numerous large pithoi found in different rooms within the settlement point to the storage of quantities of grain. In Room 81 an amphora and tub lacking spouts necessary for pouring liquids suggest grain storage. Similarly some of the ten large storage vessels found *in situ* in Room 54, the south-east pithos magazine, indicate on the

basis of no spout-holes and strongly burnt interiors that Magazine A was a cereal store. In contrast Magazine A (Room 53) contained two large vessels with spout-holes that suggest it was a liquid store, either for wine or the storage of olives in salt water.

Cereals (barley and oats) continue to be grown in eastern Crete and the Myrtos area but cultivation is now confined to parts of the plains and good arable land elsewhere. In the area and including Fournou Korifi where Myrtos was located, are extensive derelict agricultural terraces on limestone slopes. This evidence for cereal cultivation in the region suggests a tradition of cereal cultivation extending back some 4000 years.

A comprehensive topographical, agricultural and dietary survey of Crete undertaken by Allbaugh (1953) fortunately offers a basis for a comparative understanding of the role and consumption of cereals on Crete in the Minoan period. Significantly this study confirms that up to the end of World War II production and consumption of cereals on Crete had changed little since the Bronze Age. Evidence for this is seen in Minoan art, Cretan agricultural practices and products, storage facilities for grain and the equipment used. The use of a home-made wooden plough and hand-sifting of wheat on Crete in 1948 both illustrated in Allbaugh's report, indicates just how little wheat and barley production had changed in the intervening 4000 year period. No meal on Crete in 1948 was complete without bread or cereals. Even today the economic and dietary role of bread is emphasised by village shops in rural Crete that only sell loaves of fresh bread and no other commodities.

Chemically cereals such as wheat and barley are characterised by relatively low protein and high carbohydrate contents. The major portion of the carbohydrates and consequently the main source of energy provided by cereals is in the starchy endosperm. Table 4 gives the chemical composition of some common species of wheat and barley.

TABLE 4

Composition of wheat and barley (g/100g dry basis)

	Protein	Carbohydrate	Fat	Ash
Wheat: Hard red spring (HRS)	11,5	59,4	2,0	1,8
Durum	14,0	57,9	2,9	1,5
Flour	12,7	67,6	1,3	0,7
Barley: Whole grain	10,6	57,5	2,1	3,1
Pearled	10,4	62,2	1,4	1,2

Source: Lintas and Mariani-Constantini 1991 : 61, adapted from Pomeranz 1987

The protein contents of typical wheat, flour and barley sampled ranged from 11,5 to 14,0 g/100g and carbohydrate levels from 57,9 to 67,6. Whole grain barley had a corresponding protein level of 10,6 and a carbohydrate content of 57,5 g/100g (determined on a dry basis).

Fatty acids essential for good health occur in wheat and barley lipids in three types, neutral-, glyco- and phospholipids. The total lipids and individual fatty acids for samples of common wheat and barley are given below.

TABLE 5

Fatty acid composition of wheat and barley (g/100g food)  
(Fatty acids include 16:0 palmitic, 18:0 stearic, 18:1 oleic, 18:2 linoleic, 18:3 linolenic)

	<u>Saturated</u>			<u>Unsaturated</u>			
	Total	16:0	18:0	Total	18:1	18:2	18:3
Wheat, durum Whole grain	0,54	0,51	0,03	1,88	0,40	1,36	0,11
Barley Whole grain	0,48	0,45	0,02	1,51	0,24	1,14	0,13

Source: Lintas and Mariani-Constantini 1991 : 63, adapted from Pomeranz 1987

Table 5 shows that the lipids of both wheat and barley are relatively rich in the essential fatty acid linoleic acid 18:2, wheat having 1,36 g/100g food and barley 1,14. Saturated fatty acids mainly palmitic represent less than 25% of the total fatty acids for most cereals.

All cereals contain vitamins of the B group but they lack vitamins C and D. The oils of the embryos of cereal grains are however rich in vitamin E an important antioxidant. As a group cereals are low in calcium and the concentration is reduced further by the milling process (Lintas and Mariani-Constantini 1991 : 60).

The nutritional value of wheat is enhanced by a relatively high thiamine and niacin content but diminished by low calcium and riboflavin levels. In later discussion it will be shown that this low calcium content is compensated by a high calcium content in Cretan water.

The following are typical meals prepared on Crete at the time of the 1948 dietary survey (Allbaugh 1953 : 102-103). The high cereal content is clearly evident.

**Breakfast:** Bread with beverage, supplemented on occasions by olives, milk or cheese.

**Midmorning:** Bread with beverage, possibly supplemented by olives, milk or cheese.

**Midday meal:** (1) Main course consisting of one of the following:  
 (a) Vegetable alone or with cereal  
 (b) Pulses alone or with vegetable or cereal  
 (c) Fish alone or with pulses, vegetables or cereal

(2) Bread and wine.

To this about 50% of the families might add fruit, cheese, nuts or olives.

**Mid-afternoon:** One of the following: (a) Bread with fruit  
 (b) Olives  
 (c) Cheese

Sweets were sometimes served at this meal alone or as a supplement.

**Supper:** (1) One of the following:  
 (a) Leftovers from previous meal  
 (b) Fresh vegetables alone or with cereal  
 (c) Leftovers from fish, meat, eggs or fresh vegetables  
 (2) Bread and wine  
 (3) Fruit and cheese

**Sunday lunch:** In addition to bread and wine and meat alone or with pulses, many families served a fresh vegetable or cereal.  
 Fish was eaten instead of meat by some families  
 Fruit was provided as a supplement.

These meal patterns were traditional to Crete and in particular rural Crete until about 1960 (Corondialis, Ioannidis and Aravanis 1980, *cited* Pique 1988 : 102). They are certainly representative of Bronze Age diet and nutrition since all the foods mentioned were readily available on the island. The high cereal content is substantiated by the palaeobotanical evidence discussed earlier for the cultivation of wheat and barley on Crete from about 6000 BC. Average cereal consumption on Crete in 1948 was estimated to be 2,45 kg *per capita* per week. This compares with a cereal intake of 1,72 kg for the same period in the United States of America (Allbaugh 1953 : 106). Where barley was grown locally bread consisted entirely of barley, elsewhere a mixture of barley and wheat was used. *Hondros* a traditional product prepared by some 60% of families on Crete is made from crushed wheat and milk, salted and cooked and then spread in the sun to dry (*ibid* : 106).

Allbaugh's 1948 dietary survey reaffirms the importance of cereals, olive oil, fruits and vegetables, fish and meat in providing the principal nutrients of the traditional Cretan diet. According to survey estimates cereals made up 30% by weight of the total diet and provided

two-fifths of the calories and iron, one-half of the protein, thiamine and niacin, one-third of riboflavin and one-sixth of the calcium in the Cretan diet. Vegetables and fruits comprised 46% by weight and provided 8 to 14% of the calories, protein, thiamine and niacin. In addition they provided four-fifths of the ascorbic acid and vitamin A, one-fourth of the calcium and riboflavin and one-fifth of the iron.

Fish, meat, cheese, eggs, pulses and nuts comprised 10% by weight of food eaten and provided one-seventh of the calories, about one-fifth of the thiamine, vitamin A and niacin, one-third of the riboflavin and iron, two-fifths of the protein and more than one-half of the calcium in the diet. Olive oil and fats were 7% of the food consumed and supplied 29% of the calories. Beverages and sugar supplied 3% of the calories from about 4% of the food by weight (Allbaugh 1953 : 113).

The average daily *per capita* calorie consumption on Crete in 1948 based on the above dietary pattern was 2547 calories (*ibid* : 119). This compares with 3129 calories *per capita* per day for the United States of America in the same period but estimated on food purchased. The fact that the calorie intake on Crete was only 81% of that of the United States is therefore misleading since the waste factor on Crete where most food was home-produced and relatively scarce would be less than in the United States where food was plentiful. Food wastage on Crete was probably less than 200 calories *per capita* per day compared to an estimated loss of 500 to 700 calories in the United States (*ibid* : 113, 114).

The nutritional adequacy of this traditional Cretan diet high in carbohydrate (mostly cereal), low in saturated fat and containing copious quantities of olive oil was assessed comparatively against the United States National Research Council's Recommended Dietary Allowances (see Table 6). This comparison also provides a good idea of the nutritional value of earlier Minoan diet which was probably essentially similar in composition except that all carbohydrates were obtained from cereal in the absence of potatoes. The data contained in the Research Council's recommendations represents minimum nutrient requirements for average, healthy individuals, together with a 30% safety factor to cover variations in the nutritional needs of normal individual.

TABLE 6

Nutrient intake on Crete (1948) and National Research Council's (NRC) recommendations

Nutrient intake	Crete <i>per capita</i> per day consumption over 7 days	NRC recommended dietary allowance
Energy, calories	2547	2648
Protein, grams	70,70	65,10
Animal protein, grams	17,30	-
Fats/oils, grams	107,10	-
Calcium, grams	0,46	1,05
Iron, milligrams	20,10	11,60
Vitamin A, I.U.	3853	4564
Thiamin, milligrams	1,65	1,27
Riboflavin, milligrams	0,98	1,63
Niacin, milligrams	19,60	12,70
Ascorbic acid, milligrams	90,00	71,00

Source: Allbaugh 1953, Fig. 10, 119

Comparison of the calorie intake of 765 households with the Research Council's dietary recommendations showed that total calorie intake was slightly low. For vitamin A the levels were 80% of the recommendations, riboflavin 60% and calcium 50%. The average intake level of all other nutrients was greater than the Research Council's recommendations. The averages however mask a considerable range in nutritional adequacy for individual Cretan households. While certain households exceeded the recommendations by 200 calories others were up to 240 too low. Average protein intake was 70,7 grams *per capita* per day, slightly less than recommended but generally adequate. Notably 47% of protein came from cereals. Pulses, nuts and seeds provided 17% and fish, meat and wild animals 18% (see Table 6).

Calcium intake was the least satisfactory nutrient with 70% of households receiving less than 50% of the Research Council's recommended allowance. This low calcium intake probably reflects the high cereal intake (Lintas and Mariani-Constantini 1991 : 91). Calcium levels were however supplemented by vegetables grown on the island's limestone soils as well as consumption of small fish bones high in calcium but unaccounted for in the survey data. Crete's water contains on average 0,15 grams of calcium carbonate per 1000 grams, six glasses of which would increase calcium intake by 0,23 grams or about 50%. Foods boiled in this water would also contain calcium. All these supplementary sources of calcium would reduce any tendency to

calcium deficiency, either in the earlier Minoan period or in more recent years (Allbaugh 1953 : 120-122).

It is important to bear in mind that the comparative data tabulated above only indicates possible nutritional inadequacies in the traditional Cretan diet. Apart from the actual dietary survey some 200 children from low-income households in Khania in western Crete were clinically examined for evidence of malnutrition. These examinations showed no dietary deficiencies. However survey staff did notice indications of malnutrition in children of very low-income households who lived in certain mountain villages or in caves outside Herakleion. In general though the 1948 survey data together with limited clinical examinations and personal observations by survey staff all indicated that the health of the island was sound. Any malnutrition was limited to a small number of households that had very low incomes and little or no facilities to produce food (*ibid* : 124).

In summary the comprehensive dietary survey undertaken on Crete in 1948 showed that the traditional diet that had persisted for some 4000 years was nutritionally adequate. Noteworthy were the high cereal content and high consumption of olive oil. Protein obtained from fish or meat, though not great in quantity, was assessed as adequate. Where evidence of malnutrition was observed it was usually associated with poorer communities that were not agriculturally productive. The most important deficiency detected on a comparative basis was calcium, probably associated with the high cereal intake since the presence of phytic acid reduces the dietary availability of calcium and other trace elements (Armelagos *et al* 1984 : 146), but this would be compensated by other foods such as fish and cheese or the island's drinking water which is high in calcium carbonate.

It should also be noted that while, in 1948, the island could be expected to still be suffering from the effects of the World War II German occupation, Allbaugh reports that the average calorie intake of the population, at approximately 2550 calories/capita/day, was in fact slightly higher than the pre-war levels in Greece and Crete calculated by the United States Department of Agriculture at 2300-2490 - one of the lowest in Europe (1953 : 97). At 96% of the recommended minimum at the time the diet was judged adequate, but marginally so, the most important deficiency detected being calcium. There has been some controversy regarding the WHO and FAO Energy and Protein Requirements during the last twenty years as being too high

(see Foxhall and Forbes 1982 : 40, footnote 26) and the present recommended minimums do not vary greatly from those of 1948 at 2900 for young (19-24) males, 2300 for older males (25-50) and 2200 for females (Council for Scientific and Industrial Research (Foodtech), Pretoria, South Africa : Food database 1995-1996).

Allbaugh's 1948 dietary survey provides one of the few such studies that have been done and, in spite of its age, the work still provides the most detailed information on diet in modern Greece. Various authors have commented on the problems associated with attempting to reconstruct prehistoric nutrition with the information gained from modern diets and archaeological data only (*cf.* Dennell 1979 : 121-135; Foxhall and Forbes 1982; Palmer 1989 : 89-125). Foxhall and Forbes stress that "modern data do not allow us to reconstruct 'ancient diets' with any real degree of precision - there is simply not enough ancient data to do this. They are most useful as general indicators of the potential range of variables that need to be considered when studying even a simple aspect of diet and they provide a good check on assumptions about eating habits of the past" (1982 : 65). They warn that the effects of social factors such as status, income, age, sex etc remain obscure and this is particularly the case in a non-literate society such as Minoan Crete.

Dennell (1979 : 127) notes that "prehistorians would seem unwise to assume too readily that archaeological data would allow detailed modelling of these topics (i.e. diet and nutrition) in antiquity". He points out that the interpretation of evidence that is available to the archaeologist, in spite of improved excavation techniques can be heavily biased by the preservation potential and the accidents of presence and discovery. He emphasises the need for the examination of skeletal remains but warns that the data so obtained are liable to be ambiguous in distinguishing malnutrition from other causes of mortality. He does, however, state that "even if the nutritional value of a prehistoric diet cannot be precisely ascertained, it may be possible to evaluate its general composition, the likelihood that a community would experience periodic shortages or failures in food supply and the main constraints upon food production and attempts to increase it" (*ibid* : 132).

Foxhall and Forbes have attempted to assess the role of wheat and barley as a percentage of the calorie intake in classical Greece and Rome using epigraphic and literary sources, coming to the conclusion that the proportion of cereal was possibly much higher (as much as 70% of the

total calories) than Allbaugh's findings of 39% in 1948 (1953 : 107), although less grain than normal may have been eaten at that time because of wartime disruptions. They speculate that the higher grain proportion may have resulted from lower olive oil consumption than in modern times, pointing out that olive oil has always been expensive and that modern cultivars and methods of extraction are probably more productive than ancient types. Because of the attested high yield of Cretan olives however, which may have gone back to ancient times, Bronze Age Cretan consumption could have been higher than later on the mainland.

It must also be remembered that grain as a staple food essentially provides calories and does not only consist of carbohydrates but also supplies considerable amounts of protein providing, for example, 47% of the protein intake in Allbaugh's survey (1953 : 107). B vitamins and other nutrients and diets containing a high proportion of wheat and barley are less deficient in nutrients than those dependent on other types of carbohydrate such as polished rice and root crops (Foxhall and Forbes 1982 : 65).

Together with the evidence from Allbaugh's survey, the recovery of wheat and barley remains from the Early Neolithic strata at Knossos (Evans 1964 : 140), the settlements of Early Minoan Debla (Warren and Tzedhakis 1974 : 334) and Myrtos (Warren 1972 : 255, 256) demonstrates that these two crops, the mainstays of prehistoric communities in the Mediterranean, have been an important dietary component on Crete for the past 8000 years. Evidence for oats at Debla is interesting as it does not appear to have been otherwise identified in Minoan Crete (Warren and Tzedhakis 1974 : 334).

Archaeological recovery of large clay storage pithoi and architectural reconstruction of storage rooms together with Linear B references to cereals offer some idea of the quantities of wheat and barley produced in the Late Minoan period. Warren (1985 : 74-81) suggests that if the storage capacity at the palace of Knossos were divided equally between cereals, olive oil and wine, the amount of 82000 litres for cereals could be accommodated - a very substantial amount. These calculations are, of course, highly speculative.

The clay Linear B tablets recovered principally from the palaces of Knossos on Crete and Pylos and Mycenae on the mainland, date from a relatively short period and late in the Bronze Age. Their references to the allocation of rations to palace workers have been extensively s

tudied by Baumbach (1977 : 9, 10) and also by Palmer who has attempted to work out the nutritional content of the daily rations in relation to the cereals based on the work of Foxhall and Forbes. The rations of wheat and figs at Pylos (Tablets PY Ab series) and barley on Crete (KN Am 819) were analysed (Palmer 1989 : 90). Figs were apparently important at Pylos, and they appear in the Kn Fs series of tablets as part of the types of food sent in set quantities to sanctuaries together with barley, flour, wine, oil and honey, items likely to occur in the daily diet of the elite (Palmer 1989 : 102). Dried figs could have been a more important crop in the prehistoric Mediterranean than previously appreciated. Both wheat and barley are listed on the tablets and the importance of these commodities is emphasised by the quota of seventeen bakers resident at the palace at Mycenae (Tablet MY Au 102, *cited* Baumbach 1977 : 10). Palmer confirms that "wheat is the staple par excellence" and suggests that although we may not know their exact relative values, it is likely that the commercial values of commodities could have been measured in terms of wheat (*ibid* : 103). The tablets also record workers other than farmers and bakers who were concerned with cereals, one of the occupations being that of a corn-grinder - probably the miller who prepared the cereals for the bakers (Baumbach 1977 : 9).

## 5. THE OLIVE IN MINOAN CRETE

### 5.1 Evidence for the domestication of the olive, olive cultivation and oil production

Braun (1991 : 47), in an interesting paper on ancient Mediterranean foods ask the question: "Why all this reverence for the olive?". The answer is a complex one encompassing subjects as diverse as nutrition, cooking, heating, cosmetics, perfumes and unguents. In the absence of modern underground oil, olive oil would have also been used for industrial purposes such as paints, clarifiers and lubricants (although flax occurs in Linear B tablets, there is no clear evidence for knowledge of linseed oil). It is not possible on the available evidence to establish with certainty when the olive became an essential part of the Mediterranean economy but it was to become important enough to be part of the mythology of Classical Greece. The people of Athens, in particular, set great store by the olive and folklore tells how the god Poseidon and the goddess Athena once contested for the rule of the city and how the other gods decreed that whoever produced the best gift would be the winner. Poseidon, the story relates, struck the ground with his trident and produced the horse but Athena won the contest by planting an olive tree. The city was named after her and her head, together with an olive sprig, decorated the Athenian coins and the wood was used to make the seated statue of the goddess on the Acropolis. A symbolic jar of olive oil was awarded to the winner of important athletic contests.

Certainly from the Late Bronze Age, the Aegean world was using large quantities of olive oil daily and because of its good storage properties, to be discussed below, it became an important article of Mediterranean trade. The potential of the crop encouraged farmers to cultivate olives. Although the slow growth made it a long term investment, once established it was worth the considerable effort involved. As Renfrew pointed out (1972 : 304), the domestication of the olive radically altered the pattern of land use since the lesser requirements in terms of soil fertility and water enabled the cultivation of hill slopes and other marginally productive land, which was unsuitable for wheat or pulses. This resulted in a significant overall increase in agricultural production in the Aegean without competing too seriously with either the crops or animals that were previously farmed. Nutritionally, Renfrew estimates that the potential increase output in terms of calories could have been as much as 40% (*ibid* : 304, 305) but that would have probably varied greatly depending on the situation.

Olives are adapted to a climate with cool wet winters and hot dry summers, these requirements virtually demarcating the Mediterranean climate type (Jane Renfrew 1973 : 133). Around the Mediterranean the main growing areas follow the coastline of the peninsular regions situated between the Aegean, Adriatic and Tyrrhenian seas. This 'olive strip' follows the coastline in a band of varying width greater in the south and is sometimes interrupted as it occurs in Italy around the arch of the Adriatic Sea from Ravenna to Trieste.

Archaeological and palaeobotanical evidence indicates that the domesticated olive has been grown in the Aegean area for at least four millennia and probably derives from the wild olive *Olea chrysophylla* Lam which is highly polymorphic, through the wild olive, *Olea oleaster* L. or *Olea europaea* var. *oleaster* (or var. *sylvestris* Brot.) which is generally accepted as the ancestor of the domesticated olive *Olea europaea* (Jane Renfrew 1973 : 131-132). There is no clear botanical evidence of the stages of evolution with the possible exception of a morphologically intermediate form *Olea laperrini* found in the Hoggar mountains of the Sahara. In Greece, the wild olive *Olea oleaster* is still found in northern Greece (*ibid* : 132).

Since the publication in 1972 of Renfrew's 'The Emergence of Civilisation', in which he argued for the spread of the cultivation of the olive in the Aegean in the Third Millennium BC with its attendant benefits, controversy has taken place over this early date for its domestication on the grounds of insufficient evidence (*cf.* Runnels and Hansen 1986; Hansen 1988).

It is significant for the domestication of the olive in the Aegean that fossil imprints of olive leaves underlay volcanic strata dated to c. 12000 BC on the island of Santorini to the north of Crete (Renfrew 1972 : 269). This evidence suggests that wild olives were growing in the Aegean as early as the Late Wurm period which, if valid, could suggest a lengthy time during which utilisation and domestication could have taken place although Zohary and Spiegel-Roy attribute the first domestication to the Near East during the Chalcolithic and from where it only subsequently spread to the eastern Mediterranean (1975 : 319-327). The earliest evidence in the Aegean comes from the Aceramic Neolithic site of Soufi Magoula in Thessaly (Renfrew 1972 : 285) and the earliest in Crete from Early Minoan II Myrtos (Warren 1972 : 316-317), but the remains are very sparse consisting only of occasional stones.

The possibility of distinguishing the wild from the cultivated olive is very important in any attempt to ascertain when domestication commenced in the Aegean. Jane Renfrew has suggested that cultivated olives have larger stones (*ibid* : 133) - see Table 7 which records measurements of ancient olive stones from Crete, Greece, Cyprus and the Near East extending chronologically from the Early Bronze Age to the Iron Age.

TABLE 7

Comparative measurements of ancient olive stones from Crete, Greece, Cyprus and the Near East

Site	Period	Length (mm)	Breadth (mm)
Myrtos	Early Bronze Age	12,4	5,8
Lachish	Bronze Age	11,2	5,7 (av.)
El Garcel	Bronze Age	7,2-8,3	4,0-5,6
Aplike	Bronze Age	13,2	8,0
Iolkos	Late Bronze Age	11,5	5,0-6,0
Lachish	Iron Age	10,1	5,7 (av.)
Salamis	Iron Age	11,1	6,1 (av.)
Nimrud	Assyrian	10,7-12,5	5,7-7,5

Note: The number of stones in each sample is not recorded.

Source: Jane Renfrew 1973 : 133

Comparison of these measurements together with samples from Turkey and modern Greece (Table 8) suggests that stone size could possibly provide a basis for distinguishing wild from cultivated olives in an archaeological context (Zohary and Spiegel-Roy 1975 : 319-327).

TABLE 8

Comparative measurements of ancient olive stones from Crete and Greece

	Number of stones recovered	Length (mm)	Breadth (mm)
<b>Crete:</b>			
Myrtos	1	12,6	5,8
Phaistos	?	6,6-7,2	4,8-5,3
Sklavakambos	?	11,0-12,0	6,0-7,0
<b>Greece:</b>			
Dimini	1	11,2	-
Nichoria MH I	1	10,2	5,3
Nichoria LH II-III B	1	10,8	7,2
Iolkos	1	11,5	5,0-6,0
Tiryns	25	5,1-15,0	3,6-7,9

Source: Runnels and Hansen 1986 : 301

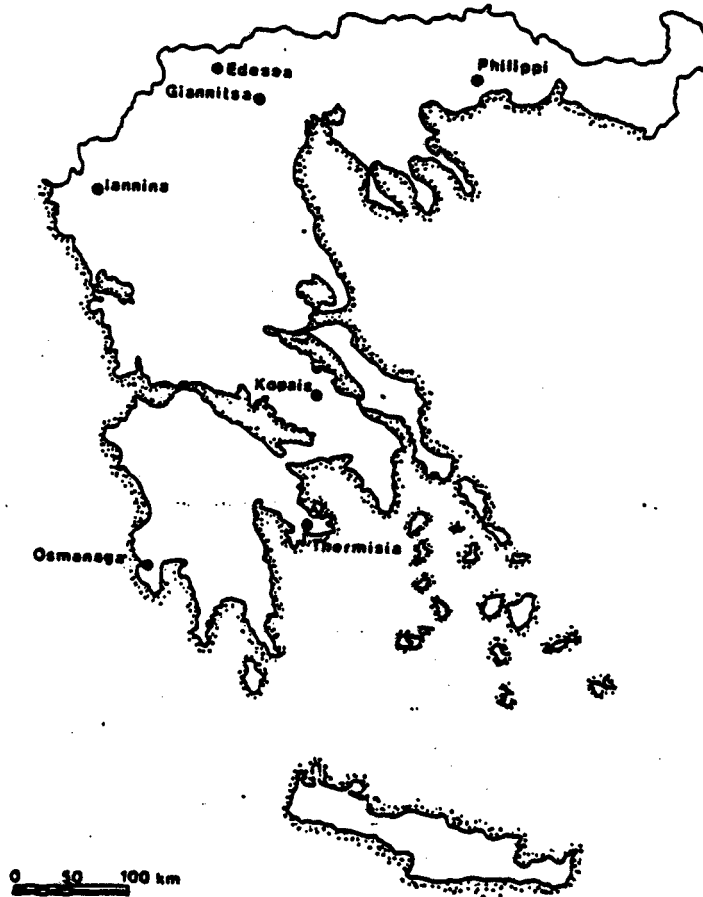
Runnels and Hansen (1986 : 301) point out, however, that the amount of overlap in the range of measurements is too great for this means of separation of the two types to be reliable and that in any case the sample is too small. As Melena points out (1983 : 99), although olive stones stand up to inhumation well, findings have been remarkably few. A possible reason lies in the fact that they would have been smashed in the pressing process and used, together with the pulp, perhaps as fodder or fuel. Hopefully stone size may eventually offer a means of differentiation and provide chronological information on the introduction of the domesticated olive, a wider range and numerically greater number of samples is required.

Olive wood and charcoal are two other organic materials recovered archaeologically that offer potential for identifying the change over from wild to cultivated olives in the Greek Bronze Age. These materials have been found at three Early Bronze Age settlements Lerna (Hopf 1961 : 239-247), Nichoria (Shay and Shay 1978 : 41-54) and Myrtos in Crete (Rackham 1972b : 299-304). Runnels and Hansen (1986 : 302) point out, however, that here again it is not possible to distinguish between wild and domesticated samples and it is possible that the wood was collected for building material or fuel rather than deliberately pruned to increase fruit yields.

Palynological evidence has also been reviewed by Runnels and Hansen (*ibid* : 303) and the sites of primary pollen cores are shown in Figure 9. They point out that although it is possible to distinguish between pollen of the wild and domesticated varieties most report the grains to genus level only (*ibid* : 302).

FIGURE 9

Sites of primary olive pollen cores in Greece  
(Source: Runnels and Hansen 1986 : 303)



There is an increase in olive pollen in north western Greece between 1350 and 1300 bc. (All uncorrected radiocarbon dates indicated by lower case bc.) In Macedonia palynological evidence for olives increases slightly about 1300 BC and then disappears, to reappear about 700 to 800 bc. In south western Greece in Messenia olives were present in small quantities as early as 2000 BC and show an increase after 1270 bc. In central Greece at Lake Kopais, pollen samples show the presence of olives for a short period as early as 3200 bc. In the southern Argolid olives appear in the record sporadically between 2000 and 1000 bc (*ibid* : 302). Samples from the Franchthi cave (mentioned earlier in context of the earliest evidence for tuna fishing and agriculture) indicate the presence of olives from the Middle to the Late Neolithic but there is a suspicion that the fossil pollen record could have been contaminated with more modern material (*ibid* : 303).

Certainly the evidence obtained by the examination of fossil pollen suggests that olives were not cultivated intensively in most areas of Greece until the Late Bronze Age. Examination of pollen cores from Crete, however, yielded a particularly early date of 3900 bc (*ibid* : 304; Gennet 1982 : 282) suggesting that the olive was cultivated in Crete earlier than elsewhere in the Aegean (Runnels and Hansen 1986 : 304).

The evidence at Myrtos, including the recovery of an olive stone, pieces of olive wood and charcoal and containers tentatively identified as olive oil separators, indicates that olive cultivation and oil production could have occurred on Crete in the Early Minoan period (c. 2200 BC) (Warren 1972 : 303). The stone was preserved by a form of fossilisation and measured 12,6 mm in length and 5,8 mm in breadth, i.e. large for a wild olive (average length 9,2 mm and width 5,6 mm) and small for a modern cultivated specimen (average length 19,1 mm and width 7,6 mm) (Jane Renfrew 1973 : 133).

Using the calculated capacities of both the pithoi and amphorae recovered, Warren made theoretical calculations of quantity of olive oil possibly stored at the time of destruction of the settlement, and consequently the number of olive trees required to produce this amount taking into account the fact that olives give a good crop only every two years (1972 : 145). The forty-four pithoi and twenty-eight amphorae had a combined storage capacity of 7125 litres. Divided theoretically between cereals, olive oil and wine Warren estimates a quantity of 2375 kilograms of olive oil and based on a yield of 5 kilograms of oil from each tree, that the number of trees probably exceeded 475. Allbaugh (1953 : 269), however, gives the amount as only 2,5 kilograms per tree which is likely to be nearer the correct figure as he emphasises that the yield per tree in Crete is greater than the rest of Greece (*ibid* : 17) so the number of trees could have been around 950 to 1000. Allbaugh (*ibid* : 545-546) records that on Crete in 1948, 1000 square metres of land was required to grow 10 to 20 olive trees. This could suggest that at Early Minoan II Myrtos some 5 to 10 hectares were under olives. Although all these estimates are highly conjectural the extensive modern olive groves and on the Hierapetra plain indicate that both the geomorphology of the region and the climate favour olive cultivation.

Rackham, who examined eighteen collections of wood charcoal from Myrtos with a stereomicroscope fitted with an annular fluorescent illuminator, ascribes some samples with certainty to the domestic olive *Olea europaea* (1972b : 300) some of the samples closely

resembling modern olive wood from the area. The proportion of olive wood to oak and pine was high comprising 85% of the total charcoal lending support to the theory that there was a handy olive grove nearby where wood could be obtained even if it meant sacrificing, or heavy pruning, of some of the less productive trees.

Rackham notes that because of the scarcity of other wood, olive wood of necessity constituted a primary roofing material. Wood charcoal appears high in the destruction layer indicating that it fell from the roof timbering, the structure originally consisting of oak, olive or pine laid at intervals wall to wall with scrap wood laid on top. At Myrtos, the buildings indicate that large roof spans were avoided at considerable inconvenience, the maximum span in a room in which charcoal was found being 2,5 metres with some rooms only 1,2 metres across.

Much of the olive wood recovered at Myrtos lacked distinctive growth rings indicating young shoots. This type of growth is encouraged by pollarding and pruning, both signs of domestication although Rackham, in a later publication (1983 : 345,346) notes that coppicing of otherwise uncultivated wild olive trees could have taken place.

Archaeological evidence for olive oil production at Myrtos rests on the discovery *in situ* of four large *lekanai* or tubs that have spouts flush with the base and which were obviously concerned with processing liquids. Of these P533 rested on a stand with its spout over a channel. In Room 17 only the base of the separator survived but was wedged on two stones in such a way that the liquid could have flowed away through a spout. P532 was placed on flat stones on the floor in Room 59. The fourth vessel P534, like P533, does appear to have been placed on a stand and was found in Room 90. Whitelaw suggests that their presence in widely separated small rooms could indicate specialised work areas (1983 : 328) probably representing the basic organisational units within the community; the replication, of this and other inferred activities probably indicating that, in terms of day to day activities, each household was independent (*ibid* : 333).

On Crete, similar tubs have been found in Late Minoan contexts at Gournia, Palaikastro, Vathypetro, Epano and Kato Zakro and in an Hellenistic house at Praisos (Warren 1972 : 138). The function of these containers has been interpreted as olive oil separators by Bosanquet (1902 : 268, *cited* Boyd-Hawes 1908) and Boyd-Hawes (1908 : 27-28, Fig. 11), and as wine presses by

Marinatos and Hirmer (1960 : 140, Pl. 62) and Platon (1964 : 164, Pl. 142a; 1965 : 218-219, Pl. 247a, *cited* Kopaka and Platon 1993). To use as an oil separator, the liquid resulting from pressing would be run into the tub where the oil would separate from the vegetable water which could be drained off through the spout at the base leaving the oil to be collected (Kritsakis and Markarkis 1987 : 461-463). There is no reason, however, why these spouted tubs should not have been used for separating both oil and wine since the processes were similar and the containers were equally suited to both uses. Their use on Crete, which spans a period of some seven hundred years from Early Minoan II to Late Minoan I, indicates that they functioned well and had an important role in the agricultural economy.

Twelve samples of suspected lipid residues recovered from the containers found at Myrtos were solvent-extracted and analysed by gas chromatography. The absence of cholesterol and the presence of triglycerides suggested vegetable oil but the results were considered to be indeterminate (Bower 1972 : 330-331). Analytical techniques have improved greatly since 1972 and the work should be repeated. A final piece of circumstantial evidence for the presence of olive oil at Myrtos came when burnt earth from jars stored in Room 22 were immersed in hot water for flotation tests for grain, the mixture appeared distinctly greasy with an oil-like film floating on the water.

This review of evidence for olive cultivation at Myrtos suggests that on purely botanical grounds, the presence and cultivation of *Olea europaea* at the settlement in the Early Bronze Age is probably questionable. The quantity of organic and inorganic evidence in the form of olive tree debris, possible oil processing equipment and oil residues all combine to indicate that, in fact, olives were cultivated and exploited economically on Crete as early as c. 2200 BC thus supporting Renfrew's assertion that domestication had taken place in Crete in the third millennium BC. The salient point is that the domestication of the olive on Crete did not take place simultaneously or at the same speed as on the mainland. The evidence, although scanty, suggests that Crete probably preceded the mainland by some one thousand years.

For the Middle and Late Bronze Age evidence is more extensive and encompasses the villages and isolated country 'villas' as well as the Minoan and Mycenaean palaces. In general settlements at 600 metres were at the upper limit for successful olive cultivation and their inability to thrive at higher altitudes would have placed limits on the choice of land for permanent

settlement. At Vathypetro, the remains of a large Minoan building dated c. 1580 BC and situated at the height of 600 metres, probably represents a farmhouse which could have also functioned as an industrial and redistribution centre for the area, many of the functions appearing to parallel those of Knossos. These also included the manufacture of pottery and textiles and the production of oil and wine. The remains of a large stone olive press and basin were found in the West Court (Castleden 1990 : Pl.1; Kopaka and Platon 1993 : Fig. 5) and sixteen storage containers from the West Wing. The Southern Sector of the house also yielded what is described as a wine or oil press but which would appear to be a separator (Kopaka and Platon 1993 : Fig. 11).

House A at Tylissos, fifteen kilometres west of Knossos and contemporary with Vathypetro, is one of three surviving substantial houses dating to the end of the Middle Minoan period and Late Minoan I. In this house a number of storage containers were found still *in situ* set on plinths and having holes near their bases suggesting that they were tapped for oil or wine.

Confusion undoubtedly exists in the literature regarding the form and function of the pieces of equipment used for processing olives and grapes in the Aegean Bronze Age. Technically they appear more suited to crushing hard olives than pressing soft grapes. On the other hand the more fragile clay spouted *lekanoi* would have been used for the secondary process of separating olive oil from the vegetable water. Bosanquet, some 90 years ago recognised the technical similarity between his find of a spouted tub in a Hellenistic house in Praisos and olive oil separators then in use on Crete (Boyd-Hawes 1908 : 27). The spouted tubs would, however, have functioned equally well in separating grape skins and pips from juice for wine making. Indeed, a seal from Chrysollakas depicts a man standing in a tub treading what are presumably grapes (Kopaka and Platon 1993).

Three probable olive press beds in Crete, all Late Minoan, are known from Knossos (Evans 1900-1901), Palaikastro (Dawkins 1904-1905) and Kommos (Shaw 1978) but no recognisable crushing tools have been found (Runnels and Hansen 1986 : 304). This suggests that olives were simply crushed with any suitable heavy stone which was later discarded. A typology and inventory of olive oil and/or wine production equipment found in Crete has been published by Kopaka and Platon (1993 : 68, 69) in which 41 items are recorded. The following table is compiled from the data provided.

TABLE 9

Minoan spouted tubs (lekanai) and stone olive presses recovered on Crete

Geographic region	Settlement	Find location	Minoan period	Type designation
*Central	Phourni	Cemetery	LM I	I
Central	Knossos	Palace (?)	LM I	I
	Knossos	House	EM II	I
Central	Mallia	House	MM I	I
	Mallia	Palace (?)	MM III	I
Central	Vathypetro	Villa	LM Ia	I
East	Gournia	House	LM Ib	I
	Gournia	House	LM Ia (?)	I
East	Myrtos	House	EM IIb	I
	Myrtos	House	EM IIb	I
	Myrtos	House	EM IIb	I
	Myrtos	House	EM IIb	I
East	Palaikastro	House	LM Ib (?)	I
	Palaikastro	House	LM I	I
	Palaikastro	House	LM Ib	I (?)
	Palaikastro	House	LM Ia	I
	Palaikastro	House	MM IIIb/LM Ia	I
East	Azokéramus	Villa	MM IIIb/LM Ia	I
East	Petras	House	LM Ia	I
East	Tourtouloi	Villa	LM Ib	I
	Tourtouloi	Villa	LM Ib	I
	Tourtouloi	Villa	LM Ib	I
East	?	Villa	MM IIIb	I
East	Choirmandres	?	MM IIIb/LM Ia	I
East	Epano Zakro	Villa	LM Ia	I
	Epano Zakro	Villa	LM Ia	I
	Kato Zakro	House	LM Ib	I
	Kato Zakro	House	LM Ib	I
	Kato Zakro	House	LM Ib	I
	Kato Zakro	House	LM I	I
	Kato Zakro	House	MM IIIb/LM Ia	I
	Kato Zakro	House	LM I	I
East	Palaikastro	House	LM Ib	II
East	Epano Zakro	Villa	LM Ia	II
	Kato Zakro	House	LM Ib	II
Central	Knossos	House	LM II/LM IIIa	III
	Knossos	House	?	III
Central	Kommos	House	LM III	III
	Kommos	House	LM IIIb	III
	Kommos	House	LM I (?) / LM II / IIIa (?)	III
Central	Phaistos	Palace	LM III (?)	III

Source: Kopaka and Platon 1993 : 68, 69 (Type designation as recorded in publication)

Table 9 indicates that three categories of Minoan stone presses or separators can be identified. Type I is a category of oil or wine separator of which 32 examples are recorded. This is the familiar *lekane* or clay tub with a spout at the base. When recovered *in situ* the tub rests on a plinth to facilitate draining the olive oil or wine into a larger container (see Kopaka and Platon 1993 : 40, Fig. 1). The Type I clay separator from Kato Zakro in the Siteia museum is a well-made robust piece of equipment with a circumference diameter of  $\pm 600$  mm obviously intended to stand up to hard use.

Only three examples of the Type II stone press are recorded. The illustration of the press from Kato Zakro is unclear, but it appears to show a stone press mounted on a permanent base with the spout positioned over a hole in the ground (see Kopaka and Platon 1993 : 40, Fig. 2.). Further examples were recovered at Epano Zakro (Platon 1964 : 165-166, *cited* Kopaka and Platon 1993 : 60) and Palaikastro (Dawkins 1902-1903 : 295, *cited* Kopaka and Platon 1993 : 59).

Type III is another type of stone press of which six examples are listed by Kopaka and Platon (1993 : 61-63). Two were recovered from houses at Knossos, one from the palace of Phaistos and three from the village of Kommos. The Type III olive press is rough stone, concave and the example from Kommos appears free-standing with a spout at one end to allow the oil and wash water to run off (see Kopaka and Platon 1993 : 40, Fig. 3).

The regional distribution of these separators and presses is noteworthy. The 32 spouted tubs were distributed over central and eastern Crete with 19% recovered in central Crete and 81% in eastern Crete. The recovery of four Type I spouted tubs at the Early Minoan II village at Myrtos in eastern Crete (Warren 1972 : 138-139) suggests a long-established tradition for their use, their primary function being for the production of olive oil. All the Type II stone presses were similarly recovered in eastern Crete. In contrast to this all six Type III presses were found in central Crete three notably associated with major palace centres.

The chronology of these tubs and presses associated with olive oil and/or wine production is also significant. With the exception of the four Type I spouted tubs from Myrtos and one from Knossos which all date to Early Minoan II, practically all of the remaining 36 tubs and presses were in use towards the end of the Middle Minoan or Late Minoan period (see Table 9). Of

these over 70% are either Late Minoan Ia or Ib, this suggesting that their use either preceded or was concurrent with the volcanic explosion on Santorini that may have adversely affected eastern and central Crete.

Analysis of the spouted tubs and presses in Table 9 relative to their find spots is enlightening. If recoveries from the Early Bronze Age, a cemetery and other questionable locations are set aside approximately 33 examples of known origin remain. Of these three were found at palaces, 21 in domestic houses and nine at country villas. Some of the houses were situated close to Knossos or Kato Zakro and others in villages such as Gournia or Palaikastro. The country villas include Vathypetro mentioned earlier and another at Epano Zakro. Halstead (1981a : 203) has suggested that remodelling of the palaces and reduction of their storage facilities coincided with the construction of the villas on Crete. Whereas some 20-30% of the ground floor area of the earlier palaces at Knossos, Mallia and Phaistos were devoted to storage, the corresponding figure at the later palace of Kato Zakro in east Crete was only about 5% (*ibid* : 203). At Phaistos and to a lesser extent at Knossos remodelling of the western facade encroached on the storage areas (Pendlebury 1939 : 150-152), while at both Mallia and Knossos new internal walls made some of the storage areas inaccessible to bulky commodities (Halstead 1981 : 203). These alterations and reductions in storage capacity at the palaces took place c. 1600 BC, some 20 years before construction of the large villa at Vathypetro commenced.

It would appear that these larger villas or industrial centres such as found at Vathypetro, Gournia and Ayia Triadha fulfilled the role of second order 'palaces', some containing substantial storage facilities the provision of these storage areas reflecting decentralisation away from the palaces. With the destruction of the villas in Late Minoan Ib presumably some degree of agricultural centralisation reverted to Knossos.

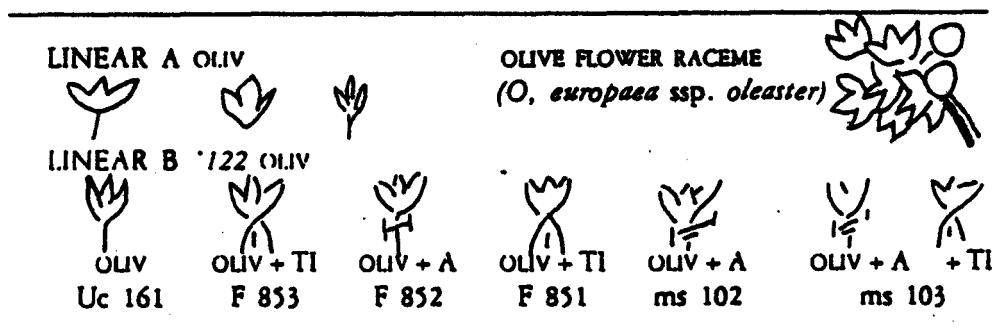
The inventory and analysis of the spouted tub and stone presses (Table 9) supports the suggestion of decentralisation of the olive industry on Minoan Crete at the end of the Middle Minoan and in the Late Minoan period. The analysis also indicates that eastern Crete in the period preceding the volcanic explosion on Santorini was probably the main region for cultivation of the olive and oil production on Crete. Olive growing and oil production in eastern Crete today remains the region's primary industry. The olive groves are extensive covering thousands of hectares and in many instances the olive trees grow in proximity to known Minoan sites. This is

particularly so at Gournia, Palaikastro and Ayia Photia. The olive oil produced at Siteia today is of high quality, as the chemical analysis in the following section demonstrates.

The textual evidence of the Linear B tablets for olive cultivation and oil production in the Late Minoan period complements the evidence obtained from pollen identification, the recovery of olive stones and finds of olive presses and oil separators on Crete. Textually the various records of olives in the Linear B tablets are accounted for by the ideogram \*122, the latter being conventionally transcribed as OLIV, tablet KN F 841.6 offering a clear context for the identification of \*122 as standing for olives (Melena 1983 : 97). It is significant in relation to the organic and inorganic evidence for olives on Crete described earlier that olives and olive oil are apparently referred to in the earlier Linear A tablets. The Linear A sign L49 is probably identified with Linear B \*122 OLIV (Raison and Pope 1971, note 44). Melena suggests that similarity exists in the Linear B and Linear A ideograms shown in Figure 10. The ideogram \*122 OLIV pictorially represents the flower of the olive tree. On the tree the whitish blossoms are carried in small upright clusters, each flower showing a cyathiform four-lobed calyx which appears as three-lobed in the front perspective drawing of ideogram \*122.

FIGURE 10

Comparison of Linear A and Linear B ideograms for olives  
(Source: Melena 1983 : 97, Table 1)



The value of the Linear B tablets as evidence for the introduction and cultivation of olives in the Greek Bronze Age is reduced by difficulties in translation and interpretation. One problem is deciding whether the tablets refer to the wild olive *Olea oleaster* or to the cultivated variety *O.*

*europaea*. Both Melena (1983 : 97) and Chadwick (1976 : 121) point out that the ideogram OLIV seldom occurs in the Linear B tablets alone, but does occur frequently in ligature with T1 and A. The assumption is that the olive ligature A stands for 'wild' and T1 for 'cultivated' olive. These ligatures are shown in Figure 10. Based on the greater frequency of OLIV + A entries than OLIVE + T1 in the tablets, Melena and Chadwick tentatively suggest that more use was made of wild olives than cultivated. Both linguists accept that this theory strains credibility, particularly as the fruit of *Olea oleaster* is smaller, harder, of poorer quality and yields less oil. The explanation offered for this anomaly is that the Mycenaeans harvested olives with a low grease content (*sic*) which were more suitable for perfumes and scented unguents.

Archaeologically this emphasis on oil from wild olives conflicts with the quantity of olive oil processing equipment found on Crete that is dated to the Middle and Late Minoan periods. The recovery of a total of forty-one separators or oil presses points to the production of a far greater quantity of olive oil than would have been needed for perfume manufacture. The olive oil industry centred in eastern and central Crete would have required extensive groves of cultivated olive trees to ensure a regular supply of olives. The linguistic dilemma as to whether wild or cultivated olives formed the bulk of the Minoan crop could have a simple explanation, since it is common practice in South Africa to graft domestic cultivars onto wild olive trees (pers. comm. CJ Molteno). This technique, which the Minoans may have been aware of, results in a hardy drought-resistant tree which yields good quality olives.

The extent and locations of the olive groves on Minoan Crete are difficult to establish with any degree of accuracy, since information on the Linear B tablets from Knossos is sketchy. The tablets do however list crop surveys that include olive trees, fig trees and even vines. Tablet KN 862 for example details a tree survey that includes the ideogram ARB on line 2 pictorially represented as an olive tree. Ideograms on line 3 may similarly represent olive trees. The olive crop from *da-wo* is recorded in tablet F(2) 852 + 8071 and on tablet F(2) 841 + 867 olive harvesting at *pa-i-to* is detailed. Melena (1983 : 105) has calculated the number of olive trees grown at these two Minoan settlements, using information obtained from the tablets combined with contemporary data on Cretan olive crop and olive yields. The theoretical number of trees and the oil produced in litres are given in Table 10.

TABLE 10

Calculated number of olive trees and oil yields from two Late Minoan settlements

Linear B tablet	Place name	OLIV	Olives		Oil yield Litres	Number of olive trees
			Litres	Kgs		
F 852	<i>da-wo</i>	90	8100	4860	826	330
F 841	<i>pa-i-to</i>	46	4140	2484	422	170

Note: For purposes of calculation

- 1 kg olives yields 0,17 litres oil
- 1 litre oil weighs 0,9 kg
- 1 litre olives weighs 0,60 kg
- 1 olive tree yields 2,5 kg oil

Source: Melena 1983 : 105, Table III

The numbers of olive trees and olive quantities estimated above suggest that the olive groves adjoining Late Minoan settlements were relatively small and differed considerably in size. *Pa-i-to* is the present area of Phaistos and both it and the second settlement *da-wo* are situated on the plain of Mesara which remains an important olive-producing region. With the stone olive press recovered at Phaistos in mind (Table 9), it is feasible that both olives and oil from these two settlements were contributed to the palace of Phaistos for storage and redistribution.

The total number of olive trees inferred on the Knossos Linear B tablets was calculated from the number of extant OLIV entries (Melena 1983 : 105). If the equivalencies used in Table 11 are again applied, the total of 902,9 units of OLIV correspond to 81 261 litres of olives from which c. 8288 litres of oil could be pressed. This theoretically represents a harvest of some 3315 trees.

Two other Linear B tablets shed light on the quantities of oil produced on Minoan Crete and provide an idea of the economic relationship between the outlying settlements and the palaces. Tablets Fh 366 and Fh 367 + 5460 record the totals of olive oil contributions to the palace of Knossos, the tablets yielding respective equivalents of 1071 and 9900 litres of olive oil. These amounts imply the produce of approximately 4000 trees for Fh 366 and 39600 trees for the oil recorded on Fh 367 + 5460. Melena (*ibid* : 105-106) points out that these olive tree totals calculated from the Fh tablets are of a similar order to figures obtained using the OLIV entries. In other words the olive oil contributions to the palace of Knossos fit in with totals recorded on the Knossos F and E tablets. The suggestion is that the 4000 trees calculated from the Knossos tablet Fh 366 could represent the size of an olive grove at Knossos. Contemporary data on olive farming on Crete records a planting density of between 15 and 18 trees per *stremma* or about 150

plants per hectare. Ancient agricultural evidence however suggests a lower density of 80 to 100 trees per hectare. The assumption is that the 4000 olive trees recorded on the tablet occupied 40 to 50 hectares (*ibid* : 106).

A difference exists between the tree totals calculated from the Knossos Fh tablets (viz. 3315 and 4000 trees) and the two Mesara settlements *da-wo* and *pa-i-to* (viz. 300 and 330 trees). These much lower tree counts recorded at outlying Late Minoan settlements are confirmed by the following estimated tree totals.

TABLE 11

Olive tree totals recorded in Linear B tablets for outlying settlements

Linear B tablet	Linear B place name	Estimated number olive trees
F 157	<i>e-ko-so</i>	300
E 670.1	<i>da-*83-ja-i</i>	326
E 669.1	<i>ti-jo</i>	325
.2	<i>da-*22-ti-jo</i>	165

Source: Melena 1983 : 105, Table III

The difference in tree counts between those recorded for Knossos and the settlements exceeds a factor of ten. This disparity suggests that the olive groves from which Knossos drew its crops were considerably larger than those of the settlements. Alternatively the tree totals recorded in the tablets could represent the combined olive harvests of many settlements.

Both the total number of olive trees and the land they occupied, calculated using archaeological evidence, considerably exceed the figures obtained using Linear B as a basis for estimates. Warren (1985 : 79) used the storage capacity of the west magazines at Knossos to determine the quantity of olive oil stored. His estimates indicate that the magazines could hold 420 pithoi each with a capacity of 586 litres giving a maximum of some 246 000 litres. On the assumption that storage would have been allotted equally to olive oil, wheat and wine, the yield from 16 000 to 32 000 trees would have been needed to fill a third of the jars. On a planting density of 100 to 120 trees per hectare the palace could have contained the harvest of 320 hectares. Using the estimate of 40 to 50 hectares for a large olive grove the calculated storage capacity of Knossos held the harvests of six large olive groves. The quantity of olive oil and the number of trees associated with its production at Knossos estimated on archaeological evidence,

considerably exceeds the totals arrived at using the Linear B tablets. Warren has suggested that the calculated quantity of olive oil stored at the palace in the Late Minoan period (some 80 000 litres) is probably an under-estimate. Olive oil was arguably the most valuable of the three commodities produced and more storage space would probably have been allocated to it. The figure of 80 000 litres of olive oil is high, however, when compared with the total of 20 000 litres of oil calculated from the Knossos Fh oil tablets.

A direct comparison between the two primary sources of evidence for olives is not acceptable for a number of reasons. Firstly the time-scale of the archaeological and Linear B evidence differs considerably. Whereas the tablets are confined to a relatively small time-span in the Late Minoan period, the archaeological and architectural evidence for storage extends back to reconstruction of Knossos in the Second Palace period c. 1700 BC. Later alterations to the palace as stated earlier suggest that the storage capacity of the west magazine was in fact reduced towards the end of the Middle Minoan period, this coinciding with the construction of the large villas such as that at Vathypetro and a move to decentralisation of agricultural storage. Secondly whereas the architectural and archaeological evidence both at Knossos and in the outlying areas for olives is substantial, that for Linear B is scanty. Archaeologically the existence of oil storage facilities at the palace are reinforced by the recovery of stone oil presses and clay separators. In contrast to this the details of olive oil and olive trees we gather from the tablets are specific to the tablets recovered. Unlike storage facilities which provide some basis for an estimate of the total palace capacity for olive oil, the tablets may record donations to the palace at a particular time (Dickinson 1994 : 76).

The palynological, botanical and archaeological evidence suggests that olive cultivation on Crete had its inception in the Early Minoan period. The archaeological evidence reinforced by the Linear B tablets justifies the assumption that from the Middle Minoan period to the demise of Knossos sometime after 1400 BC olive growing and oil production on Crete was an important agricultural activity. The evidence indicates that Knossos had recourse to larger quantities of olives and greater storage facilities for oil than did the villas in the outlying hamlets. Both the inhabitants of the villas and people of villages in closer proximity to Knossos would probably have contributed to the palace economy.

It is impossible to establish with any accuracy just how much land on Minoan Crete was devoted to olive cultivation. Hutchinson (1962 : 41) points out that large areas of Crete have always been unproductive and that as late as 1948 only ten per cent of the island was devoted to olives, vines and other fruit orchards. Crete however has always produced good olives with a high oil yield, some 74% above the average for Greece. This higher oil yield of olives grown on Crete is partly attributed to more frequent pruning of the trees. On Crete 80% of the olive trees are pruned at least once and some twice every five years. This pruning which is unique to Crete is said to have its inception in the Minoan period (Allbaugh 1953 : 272).

The main olive-growing regions on Crete are today located near Ierapetra and Khania. Other important areas are situated on the north coast at Kastelli-Kisames, Kastelli-Pedhiadhos, east of Rethymnon and in east Crete close to Siteia. Particularly big olive groves are to be found at Palaiokhora and in the Mesara. It is significant that many Minoan palace names on Crete are associated with areas of good olive production, Phaistos or *pa-i-to* on the Mesara plain and Knossos itself being just two examples.

#### PLATE 1

Extensive olive cultivation on Siteia mountains, eastern Crete



## **5.2 The dietary and nutritional benefits of traditional cold-pressed olive oil**

Although the traditional Mediterranean diet is proposed as a model for healthy eating habits, discontinuities exist in the dietary patterns of different Mediterranean countries. Earlier discussion showed for example that the diets of the people of southern and northern Italy differ in the quantity of olive oil consumed. Whereas the people of the southern region favour a high consumption of olive oil their northern counterparts prefer a less health-beneficial diet containing more saturated animal fat. Discussion has also shown that the diet of southern Mediterranean countries which include Crete and Greece is characterised by a high intake of cereals, copious quantities of olive oil and a low consumption of animal fat.

The dietary patterns of fourteen Mediterranean countries have been compared with the food allowances recommended by the European Atherosclerosis Society (Study Group of the EAS 1987) (Fidanza and Versigliani 1987). These include the following:

- (i) Total fat consumption should be less than 30% of the caloric intake.
- (ii) Saturated fatty acids should be reduced to less than 10% and cholesterol to less than 300 mg-day
- (iii) Consumption of complex carbohydrates should be kept above 50% of the total caloric intake, especially of foods rich in fibre and of vegetable origin

The dietary patterns of fourteen Mediterranean countries together with the United States of America are compared with the European Atherosclerosis Society's recommended food allowances in Figure 11. In the graph the nutrients are represented as a percentage of the total daily calories, contrasted against the food allowances recommended by the European Atherosclerosis Society.

FIGURE 11

Comparison of dietary composition of 14 Mediterranean countries and the United States of America with the recommended food allowance of the EAS  
(Source: Giacco and Riccardi 1991 : 7, Fig. 1-2)

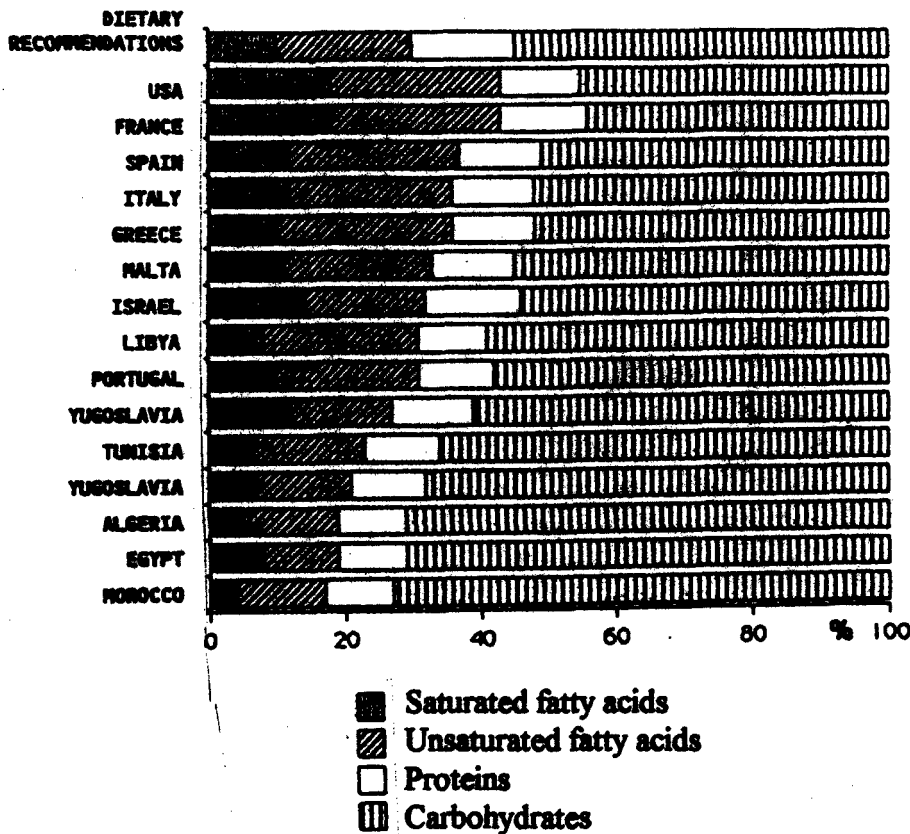


Figure 11 shows that the dietary composition of eight of the fourteen Mediterranean countries conforms to the EAS recommendation that the consumption of saturated fatty acids should represent less than 10% of the total caloric intake. The countries that conform are Greece, Morocco, Egypt, Algeria, Turkey, Tunisia, Libya and Portugal. These are all countries that traditionally have a high consumption of olive oil. In a further five countries the saturated fatty acid intake is between 11 and 14%. In France and the United States (both consumers of animal fats) the consumption of saturated fatty acids rises to 18%.

Six Mediterranean countries conform to the EAS recommendation that the total fat consumption should represent less than 30% of the total caloric intake. These countries are Yugoslavia, Tunisia, Algeria, Egypt, Turkey and Morocco. Greece, Spain, Portugal, Italy, Israel, Libya and Malta are just above the recommended consumption figure of 30%. Both France and the United States have high total fat intakes of 43%.

Thirteen of the fourteen Mediterranean countries correspond to the European Atherosclerosis Society's recommendation for carbohydrate consumption of >50%. France is again however the exception, notwithstanding its Mediterranean connection with a total carbohydrate consumption of only 43%.

The analysis shown in Figure 11 demonstrates that there is a common nutritional profile for most Mediterranean countries. This profile is characterised by the following:

- (i) a low consumption of animal fat,
- (ii) a high consumption of complex carbohydrates,
- (iii) a moderate intake of total fat with a preference for mono-unsaturated fat in the form of olive oil.

These characteristics reportedly confirm the adequacy of the Mediterranean diet for preventing cardiovascular and other chronic degenerative diseases (Giacco and Riccardi 1991 : 8).

The following tables contain chemical analyses of the fatty acid composition of typical Greek and Cretan cold-pressed virgin olive oils.

TABLE 12

Fatty acid composition (%) of three Greek cold-pressed virgin olive oils

Fatty acid	Greek commercial olive oil (1) (Elanthy)	Greek commercial olive oil (2) (ex Dr Moltano)	Greek commercial olive oil (3) (Calamata)
C16:0 Palmitic	11,2	10,7	10,0
C17:0	-	-	-
C18:0 Stearic	2,5	2,5	3,0
C20:0	0,3	-	-
C22:0	-	-	-
C24:0	0,3	0,2	-
<b>Total saturated</b>	<b>14,3</b>	<b>13,4</b>	<b>13,0</b>
C16:1 Palmitoleic	0,7	0,3	0,6
C18:1 $n$ -9 Oleic*	75,4	77,2	72,0
C18:1 $n$ -7	2,3	2,5	-
C20:1	-	-	-
<b>Total monoenes</b>	<b>78,4</b>	<b>80,0</b>	<b>72,6</b>
C16:4	-	-	-
C16:3	-	-	-
C18:2 Linoleic	7,3	6,5	12,5
C20:4 $n$ -6	-	-	-
C20:5 $n$ -3 EPA	-	-	-
C20:4 $n$ -3	-	-	-
C20:3	-	-	-
C22:6 $n$ -3 DHA	-	-	-
<b>Total polyunsaturated</b>	<b>7,3</b>	<b>6,5</b>	<b>12,5</b>
Unidentified	-	-	1,9

\*Includes C18:3 $n$ -3

Source: Fishing Industry Research Institute, Cape Town

TABLE 13

Fatty acid composition (%) of various olive oils

Fatty acid	Greek commercial oil (4) (Anias)	South African commercial cold-pressed virgin olive oil	Greek commercial olive oil (5) (Samos)*	Olive oil ex Siteia
C16:0 Palmitic	10,5	9,8	19,2	16,0
C17:0	0,1	0,1	-	-
C18:0 Stearic	2,7	3,5	2,5	2,5
C20:0	0,5	0,3	-	0,2
C22:0	-	0,1	-	-
C24:0	-	0,3	-	-
<b>Total saturated</b>	<b>13,8</b>	<b>14,1</b>	<b>21,7</b>	<b>18,7</b>
C16:1 Palmitoleic	0,6	0,6	0,4	0,7
C18:1n-9 Oleic	74,2	78,2	18,0	69,2
C18:1n-7	1,4	1,7	-	1,8
C20:1	0,2	0,2	-	-
<b>Total monoenes</b>	<b>76,4</b>	<b>80,7</b>	<b>18,4</b>	<b>71,7</b>
C16:4	0,4	-	-	-
C16:3	-	0,1	-	-
C18:2 Linoleic	7,6	5,3	57,0	9,4
C20:4n-6	-	-	-	-
C20:5n-3 EPA	-	-	-	-
C20:4n-3	-	-	-	-
C20:3	0,2	-	-	-
C22:6n-3 DHA	-	-	-	-
<b>Total poly unsaturated</b>	<b>8,2</b>	<b>5,4</b>	<b>57,0</b>	<b>9,4</b>
Unidentified	1,6	-	2,9	0,2

\*Adulterated

Source: Fishing Industry Research Institute, Cape Town

The analyses of four of the five Greek commercial cold-pressed virgin olive oils show a good uniformity of fatty acid composition. Oleic acid contents vary from 72,0 to 77,2% and the linoleic acid content from 6,5 to a high of 12,5% for oil made from Calamata olives. The palmitic acid content varies from 10,0 to 11,2%. These differences in fatty acid composition are attributable to factors such as climate or the use of different varieties of olive.

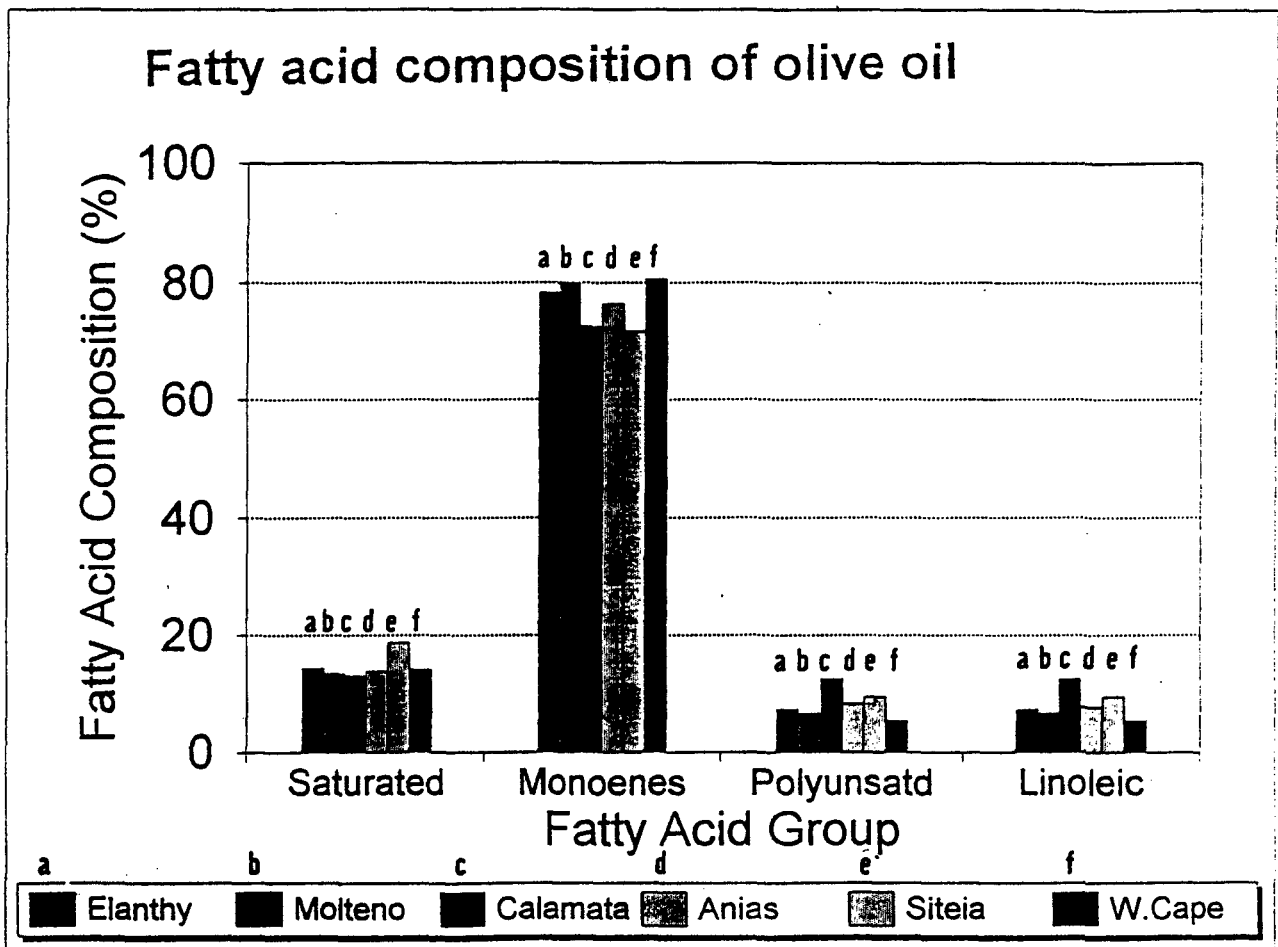
For comparative purposes a South African cold-pressed olive oil produced in the Western Cape is included in the analyses, this showing reasonable conformity in fatty acid composition with the Greek oils.

A Greek olive oil sample from the island of Samos is also included in the table. This oil shows adulteration, the addition of an unknown substance (possibly Bulgarian sunflower seed oil) producing a markedly lower oleic acid content with an associated rise in the level of linoleic acid. The analysis of the Cretan olive oil processed by the factory near Ayia Photia demonstrates that the oil is of excellent nutritional quality and comparable in oleic, stearic and linoleic acid contents with the Greek olive oil sampled (numbers 1 to 4). The C16:0 palmitic acid content of the Cretan oil is the highest recorded.

Figure 12 shows a comparative computer analysis of the fatty acid composition (%) of all six olive oils. The graph demonstrates that the Cretan oil has above average polyunsaturated and linoleic acid levels.

FIGURE 12

Comparative computer analysis of olive oils from Greece, Crete and Western Cape



Early research into the relationship between dietary patterns and health suggested that the polyunsaturated fats obtained principally from fish lipids were cholesterol-lowering, whereas saturated fats of animal origin were cholesterol-raising (Duthie and Barlow 1992 : 20-36). The mono-unsaturated fats of vegetable origin such as olive oil were accorded a neutral role and received scant attention. Attention focused almost exclusively on the ratio of polyunsaturated to saturated fat. It was not until 1980 when Keys published 'Seven Countries: A Multivariate Analysis of Death and Coronary Disease' that the important connection between olive oil and health became apparent. This study demonstrated that the Mediterranean people who for many millennia had consumed a high mono-unsaturated fat olive oil rich diet had comparatively low total cholesterol levels with an associated low incidence of coronary heart disease (Fogerty 1989 : 36-44). Table 2 showed the low number of deaths from heart disease in Mediterranean countries, the data revealing that Crete had only 38 recorded deaths per 10000 from heart disease over a fifteen year period.

Concurrent with the discovery of this relationship between olive oil consumption and the absence of heart pathology, studies were undertaken focusing on the effect of high intakes of linoleic acid. Table 13 shows that the linoleic acid is a component of olive oil, the content of the Greek oils analysed varying between 6,5 and 12,5%. The Cretan oil had a linoleic content of 9,4%. The studies revealed that along with lowering both total serum cholesterol and low density lipoprotein cholesterol, a high intake of linoleic acid also reduced high density lipoprotein cholesterol. Not all studies supported this last finding and it was suggested that the variable results obtained reflected different levels of total linoleic acid in the diets or even differences in the composition of the olive oil.

In another study the beneficial health effect of a mono-unsaturated fat (olive oil) was compared with a polyunsaturated fat (linoleic acid) (Mattison and Grundy 1985 : 194-202). This research demonstrated that olive oil with its high percentage of oleic acid (between 72 and 77% in the Greek oils sampled and 69,2 in the Cretan oil) was as effective as linoleic acid in reducing both total and low density lipoprotein cholesterol levels. However while linoleic acid produced a reduction in high density lipoprotein cholesterol, the diet rich in olive oil did not produce the same effect.

Yet another study compared the serum cholesterol-lowering effect of a high mono-unsaturated fat diet with a low fat diet (Grundy 1986 : 745-748). Both diets reduced the total cholesterol and low density lipoprotein cholesterol, with the high mono-unsaturated fat diet proving the more effective. Both diets were then compared with a third diet high in saturated animal fat, the low fat and rich mono-unsaturated fat diets proving clinically more beneficial.

The results of this work prompted Grundy to suggest that serious consideration be given to the use of mono-unsaturated fatty acids as a hypocholesterolaemic agent.

Other work using olive oil was carried out by Mensink and Katan (1987 : 122-125) who compared the effects of a diet high in mono-unsaturated fatty acids in the form of olive oil with a diet high in carbohydrates. The high carbohydrate-high fibre diet achieved a reduction in total cholesterol and high density lipoprotein cholesterol, whilst the high olive oil diet resulted in a comparable reduction in total cholesterol but left the high density lipoprotein cholesterol unchanged.

A rather controversial study was undertaken by Aravanis *et al* (1988 : 777-1123) on rural Cretan boys fed a diet rich in olive oil. This study suggested that a high olive oil diet did not produce lower low density lipoprotein cholesterol levels. The study suggested furthermore that the total cholesterol levels of the rural Cretan boys exceeded those of their American counterparts. The reasons for these anomalous results remain unexplained.

A further dietary study involving olive oil was undertaken by Baggio *et al* (1988 : 960-964). In this work eleven young volunteers who were admitted to a metabolic ward were given an olive oil enriched diet. The high consumption of olive oil resulted in a significant decrease in mean total cholesterol, low density lipoprotein cholesterol as well as a reduction in total triglycerides. The total high density lipoprotein remained unchanged, confirming the results obtained by earlier workers. Baggio *et al* concluded that olive oil, a natural fat, was suitable for the control of total cholesterol and low density lipoprotein cholesterol. They suggested furthermore that olive oil offered a valid alternative to the polyunsaturated fatty acids obtained primarily from fish lipids. Ackman (pers. comm.) points out that the implication of a 1:1 match of olive oil and fish oil is incorrect, probably 40:1 being more realistic.

In yet another study the effect of an olive oil rich diet was compared with a complex carbohydrate diet (Mensink and Katan 1989 : 436-441). Forty-eight healthy males and females were fed a high saturated fatty acid diet for 17 days and thereafter were divided into two groups of 24. One group was then given a diet high in complex carbohydrates for 36 days and the other group an olive oil rich diet for a similar period. The results demonstrated that the serum cholesterol levels of those on the carbohydrate rich diet fell by 0,44 mmol/L (16 mg/dl). The decrease for the volunteers on the olive oil diet was slightly higher, 0,52 mmol/L (20 mg/dl). In contrast to other dietary trials in this research both the high density lipoprotein and the low density lipoprotein cholesterol contents were reduced.

In one of the most recent dietary experiments involving consumption of mono-unsaturated fatty acids Ginsberg *et al* compared the reduction of cholesterol in normal males on the American Heart Association's Step I diet with others on the same diet, but supplemented by mono-unsaturated fatty acids (Ginsberg, Barr and Gilbert 1990 : 574-579). The fatty acid composition of the diets was as follows:

American Heart Association (AHA) Step I diet:

10% saturated fat	
10% mono-unsaturated fat	
10% polyunsaturated fat	Cholesterol content 250 mg/day

Mono-unsaturated fatty acid enriched AHA Step I diet:

10% saturated Fat	
18% mono-unsaturated fat	
10% polyunsaturated fat	Cholesterol content 250 mg/day

The dietary effects of the AHA Step I diet and the modified AHA Step I diet were then compared with volunteers on the average United States diet that contained an estimated cholesterol content of 500 mg/day.

This particular dietary experiment demonstrated that both the AHA Step I diet and the same diet enriched with mono-unsaturated fatty acids produced significant reductions in total cholesterol levels. However neither the plasma triglyceride levels nor the high density lipoprotein cholesterol contents altered significantly with either diet. The results obtained indicated that the

diet recommended by the American Heart Association was effective, but was not markedly improved by the further addition of mono-unsaturated fatty acids.

Finally a study carried out in 1990 investigated the inter-relationship between olive and vegetable oil consumption and coronary heart disease (Trevisan *et al* 1990 : 688). This research suggested that in both males and females consumption of olive oil as well as other vegetable oils was inversely associated with serum cholesterol, glucose levels and systolic blood pressure.

It is unfortunate that much of the research carried out on the beneficial effects of olive oil consumption is technically inferior to that done on the *n*-3 polyunsaturated fatty acids derived from fish oils which is covered in the next section. Emphasis is generally placed on the beneficial effects of olive oil consumption in the diet, with the results assessed comparatively rather than quantitatively. Technically many studies lack analytical data on the composition of the oil, a knowledge of which is a prerequisite since olive oil is a natural substance and varies in composition. In some publications reviewed olive oil is equated in a general way with mono-unsaturated fatty acids, the equating of which could lead to erroneous conclusions. In yet other work of a dietary nature the method of consumption is not clarified. For example it is necessary to point out whether the olive oil was merely consumed raw as salad dressing, or alternatively was used as a cooking fat, with the possibility of chemical changes caused by heating.

Notwithstanding these technical imperfections in the research on the beneficial effects of olive oil consumption, it is evident that olive oil is a superior dietary alternative to saturated animal fat. The epidemiological evidence from the southern Mediterranean regions, including the Aegean, overwhelmingly supports the benefits of the inclusion in the diet of mono-unsaturated fatty acids obtained from olive oil.

On Crete olive oil together with a moderate consumption of saturated animal fat and carbohydrates of plant origin, supplemented by fish, has formed the basis of a sound dietary pattern for some four millennia. It is noteworthy that in the rural villages and the smaller coastal towns this traditional diet still remains the basis of Cretan nutrition. In the traditional diet the four primary components are best seen as being complementary to one another, the diet as a whole contributing the optimum beneficial effect on health. This assumption is supported by

modern medical recommendations such as those of the European Atherosclerosis Society (Fidanza and Versiglioni 1987 : *Tabelle di Composizione Degli Alimenti*. Idelson).

Finally there is a question raised by Spiller (1991b : 189) of the possibility of an excess of mono-unsaturated fatty acids in the diet brought about by an over-consumption of olive oil. Allbaugh (1953 : 111) has pointed out that the traditional diet on Crete contains up to 85 grams per day of fats, chiefly olive oil. The question of a safe level of mono-unsaturated fats in the human diet remains as yet unclarified. Spiller has suggested however that mono-unsaturated fats are probably the only type of fat that could exceed the now popular recommendation of 30% kcal of fat in the diet and which would not lead to undesirable side effects.

Notwithstanding the ready availability of olive oil in Greece and Crete and the associated nutritional benefit of a mono-unsaturated oil, socio-economic development since World War II has brought with it a decline in dietary habits. This decline, seen particularly in the industrialised centre of Herakleion and the westernised holiday towns such as Ayios Nikolaos includes a higher cholesterol intake and a lower fibre consumption. On Crete as mentioned earlier these dietary changes are accompanied by the appearance of cardiovascular disease that was previously absent (Corondialis *et al* 1980, *cited* Pique 1988 : 102).

### 5.3 Chemical properties and storage stability of olive oil

Olive oil is the traditional fat used for culinary purposes by the people of the Mediterranean basin. The 'olive oil strip', as mentioned earlier, follows the peninsular regions situated between the three Mediterranean seas, the Aegean, Adriatic and Tyrrhenian. Along these shores the band of olive oil consumers has widened and weakened over the past four millennia. By choice the Mediterranean people consume fat as a liquid instead of a solid. This preference for olive oil as a staple lipid confers the important nutritional benefit of a monounsaturated fat, instead of the more common but less health beneficial saturated fats of animal origin. Because the consumption of animal fat in the southern Mediterranean area is low the daily consumption of cholesterol is correspondingly much lower than in the more northern countries (Berra and Rapelli 1986 : 308-311).

The olive is a delicate fruit that takes three months to ripen. Chemically olives consist of 50% water, 30% solids and 20% oil and because of the high moisture content the fruit has to be processed promptly after harvesting to avoid damage caused by enzymes (Fedeli and Testolin 1991 : 129). Two primary factors determine the quality of olives, these factors being environmental and agronomic (Cimato 1990 : 20-31).

Olive oil is composed of a mixture of triglycerides. These triglycerides have predominantly monounsaturated fatty acids esterified to glycerol. It is this unsaturation that makes the fat more fluid and lowers the melting point. To a lesser extent the oil also contains saturated fatty acids esterified to glycerol. The commonest monounsaturated fatty acid is oleic acid (18:1) the main component that distinguishes olive oil from other oils. It also contains palmitoleic acid (16:1) in smaller amounts. The saturated fatty acids that olive oil contains are palmitic (16:0) and stearic acid (18:0) (see Table 15) (*ibid* : 21).

Olive oil also contains other fatty acids notably linoleic (18:2) and linolenic (18:3) acids (see Table 40 for structures) which being polyunsaturated have more than one double bond. These fatty acids present in olive oil are known as essential fatty acids because the human body is unable to synthesise them. They can only be obtained through the diet. Apart from the energy which diet supplies, the linoleic and linolenic fatty acids are important because they control primary biochemical mechanisms in the human body (*ibid* : 21).

The approximate proportions that these fatty acids have in the acid composition of cold pressed olive oil are given below.

TABLE 14  
Fatty acid composition per cent of cold-pressed  
(virgin) olive oil

Fatty acid	% Composition
Oleic 18:1	63,0 - 83,0
Palmitoleic 16:1	0,3 - 3,0
Palmitic 16:0	7,0 - 17,0
Linoleic 18:2	Max. 13,5
Linolenic 18:3	Max. 1,5

Source: Cimato 1990 : 23, Table 2

Apart from the nutritionally beneficial fatty acids listed in Table 14 the non-triglyceride fraction of olive oil (0,5 - 2%) comprises other substances that have been chemically identified. These include hydrocarbons, waxes, sterols, alcohols, pigments and tocopherols. These compounds present in olive oil are also of dietary and organoleptic importance since some have therapeutic value, others account for aromatic flavour in the oil and yet others are effective antioxidants such as tocopherols that make olive oil resistant to ageing (Montedoro and Garofolo 1984 : 157-167). The presence of these natural antioxidants, and their retention during pressing of the olives and separation of the water and oil mixture, had important economic consequences for the storage of large quantities of olive oil in the Minoan palaces on Crete.

The stability and keeping properties of olive oil are controlled mainly by the tocopherols, 90% of which are in the biologically active alpha form. Tocopherols were amongst the earliest fat soluble antioxidants isolated from plant sources. Naturally present in olives they are responsible for the enhanced oxidative stability of other vegetable oils such as peanut or cottonseed oils relative to animal fats. Tocopherols prevent lipid oxidation by stopping free radical chain reactions by donating a hydrogen atom to a hydroperoxyl radical. The resulting tocopherol radical is relatively stable and does not continue the chain reaction. Alpha-tocopherol is the best known of the tocopherols and is more commonly called vitamin E.

The retention of these desirable antioxidants present in olive oil depends on such variable factors as the specific olive cultivar used, the maturation and conservation of the fruit and in particular the method of oil extraction. Cold pressing of the olives using relatively low pressure is still acknowledged as the best method of producing top quality oils with a high antioxidant polyphenolic and tocopherol content (Cimato 1990 : 22).

Information on the antioxidant content of Greek and Cretan olives and olive oils is surprisingly scanty. Analytical data available suggests however that the tocopherol contents of the highest quality Greek ('virgin') olive oils though differing from one geographic region to another are of a satisfactory standard (Manoukas and Hasapidou 1989 : 604, 607). The tocopherol contents of three varieties of Greek olives and four olive oils from different regions were determined by high performance liquid chromatography (HPLC) and are shown in Tables 15 and 16.

TABLE 15

Tocopherol and tocotrienol composition (mg/kg fat) of three varieties of Greek olives (6-9 samples/mean)

Variety of olive	Tocopherols			$\alpha$ -tocotrienol	$\alpha$ -tocopherol equivalent
	$\alpha$	$\beta$	$\gamma$		
<b>Conservolia</b>					
Green	138	tr.	tr.	tr.	138
Black	170	26	36	28	189
<b>Calamata</b>					
Black	174	26	37	50	196
<b>Halkidiki</b>					
Green	130	tr.	23	tr.	132

tr. = trace

Source: Manoukas and Hasapidou 1989 : 606

TABLE 16

The tocopherol content (mean of 6-9 samples) of virgin olive oil (mg/kg fat)

Tocopherol	Locality of olive trees				
	Lassithi*	Messinia	Larissa	Arta	Halkidiki
$\alpha$ -tocopherol	108	107	142	126	81
$\gamma$ -tocopherol	tr.	15	tr.	20	17

\*Crete

tr. = trace

Source: Manoukas and Hasapidou 1989 : 606

Table 15 contains the analyses for the three main varieties of edible Greek olives. *Conservolia* is the most important table variety representing some 70% of the Greek crop and being mostly cultivated in central Greece. *Calamata* is a variety of *Olea europaea* grown in the southern part of Greece and produces black olives of excellent quality. *Halkidiki* is the third variety and is cultivated in northern Greece producing green olives of good quality (*ibid* : 604).

Table 16 contains tocopherol contents of olive oils processed under conditions that reportedly did not lead to deterioration of the oil. The cold pressed oil was made from olives grown in southern Greece (Crete, Messinia), central Greece (Larissa, Arta) and northern Greece (Halkidiki). The researchers note that every effort was made to select samples that would give significant and comparable results (*ibid* : 606).

Analyses of the antioxidants in three varieties of olives indicate quantitatively that  $\alpha$ -tocopherol is the predominant tocopherol in Greek and Cretan olives. The analyses also reveal that the tocopherol content of olives depends on the state of maturity of the fruit. Green *Conservolia* (early stage) contained lower levels of  $\alpha$ - and  $\gamma$ -tocopherol than black (later stage) olives. *Conservolia* black olives also contained  $\beta$ - and  $\gamma$ -tocopherol and  $\alpha$ -tocotrienol that was absent in green olives. *Calamata* black olives furthermore contained more  $\alpha$ -tocopherol than black *Conservolia* olives (*ibid* : 605).

Table 16 demonstrates that the content of this important natural antioxidant differs quantitatively in olives harvested in the various regions of Greece. Olive oil from central Greece gave the highest  $\alpha$ -tocopherol content, the northern region the lowest and southern Greece and Crete in-between values. These differences are influenced by environmental factors such as soil and rainfall as well as the cultivar grown. Manoukas and Hasapidou state however that the tocopherol values obtained generally agree with those published by other workers (Carpenter 1979; McLaughlin and Wihrauch 1979; Gracian Tous 1966, *cited* Manoukas and Hasapidou 1989 : 605).

With  $\alpha$ -tocopherol contents for Crete and southern and central Greece available, these varying from 107 to 142 mg/kg, the question arises as to what level of the natural antioxidant is required in olive oil to achieve optimum stability. Clarke, Hunsiker and Megremis (1990 : 262-263) demonstrated that the antioxidant activity of  $\alpha$ -tocopherol relates to the degree of

saturation of a fat. Experimentally the addition of tocopherol to peanut, cottonseed and soybean oils resulted in only a small increase in stability and storage life, since the oils contained the natural antioxidant near the optimum concentration. Conversely the addition of tocopherol to fats of animal origin produced a dramatic increase in oxidative stability. The optimum level of  $\alpha$ -tocopherol in vegetable oils such as peanut, cottonseed and soybean is between 200 and 400 mg/kg, a plateau effect being apparently achieved at these levels (*ibid* : 262-263).

The  $\alpha$ -tocopherol content of stone-pressed virgin oil reported as from Lasithi, but probably from the *district* of Lasithi, i.e. Nomos Lasithiou in Crete, was 108 mg/kg, 92 mg/kg below the lower point at which optimum antioxidant effect was experimentally achieved in other vegetable oils. Manoukas and Hasapidou (1989 : 606) point out however that olive oil is unique in that the  $\alpha$ -tocopherol equivalent to polyunsaturated fatty acid ratio is the highest of all common seed oils .

Cold-pressed olive oil is a better balanced oil from the point of view of storage life and stability than other vegetable oils. With an  $\alpha$ -tocopherol content probably exceeding 100 mg/kg, the stone-pressed olive oils produced on Crete in the traditional manner in the Minoan period would have had a good organoleptic quality with a satisfactory storage life. On chemical evidence there is thus no reason why large quantities of stable olive oil could not have been stored at Knossos and other Minoan palaces for a reasonable period of time.

Apart from the antioxidant properties inherent in the tocopherol content of the oil, olive oil contains another chemical compound that can retard ageing of oil under storage. Cold-pressed virgin quality olive oil produced on Crete in the Bronze Age would have been relatively rich in chlorophyll, the compound that imparts the characteristic greenish colour to the oil. This pigment is composed primarily of chlorophylls *a* and *b* and their degradation products pheophytin *a* and *b*. The amount of these chlorophyll pigments in Minoan olive oil would have depended on factors such as the variety and ripeness of the olives and storage conditions. In freshly extracted cold-pressed virgin olive oil the content of chlorophyll *a* and *b* varies from 1 to 10 mg/kg while the pheophytin *a* and *b* content is 0,2 to 24 mg/kg (Rahmani 1989 : 30-32).

Some two decades ago research showed that both chlorophyll *a* and *b* and pheophytin *a* and *b* had pro-oxidant and antioxidant activities (Interesse, Ruggiero and Vitagliano 1971 :

318-324). Photo-oxidation is induced by chlorophylls and pheophytins when olive oil is exposed to sunlight. This photo-oxidation contributes to the formation of free radicals needed to set autoxidative processes in motion. If however olive oil is stored in the absence of sunlight the compounds have antioxidant properties, pheophytin *b* proving to have the most pronounced activity both as a pro-oxidant and as an antioxidant. These findings that chlorophyll pigments in olive oil can have an antioxidant effect suggest that the shelf-life of Minoan olive oil was actually increased by its storage in the dark palace magazines. Containment of the oil in large clay pithoi contributed further to an absence of sunlight and photo-oxidation.

Beta-carotene, another chemical compound found naturally in olive oil, has also been shown to significantly delay oxidation (Kiritsakis and Dugan 1985 : 892-896). Present in quantities of about 4 mg/kg of oil, beta-carotene is a singlet oxygen deactivator and an inhibitor of chlorophyll-induced photo-oxidation in olive oil.

Ackman (pers.comm.) points out that in processing olives it is desirable that the phytonutrients of olive oil be left undisturbed in the oil.

Apart from these advantageous chemical properties of olive oil that contributed to the production of an economically sound product, the quality of Minoan oil was enhanced by the use of stone oil presses and clay separators. Siliceous stone presses are still considered to produce the finest olive oil, and the use of clay spouted separators would have allowed time for equilibrium to be reached between the mixture of water and oil.

The archaeological evidence and chemical analysis of traditional Cretan olive oil thus points to a successful olive oil industry that flourished on Crete particularly towards the end of the Middle and Late Minoan period. The distribution of artefacts associated with olive oil production suggests that this industry was located in eastern and central Crete. The oil produced on Crete in the Bronze Age, on the basis of the equipment used and chemical analysis of traditional oil, was probably equal in quality to the best cold-pressed virgin oil produced in Greece today. As such, Minoan oil would have offered trade potential with other Mediterranean lands.

## 6. FISHERY RESOURCE EXPLOITATION IN MINOAN CRETE

### 6.1 The topography, hydrography and fish stocks of the Mediterranean and the Aegean

The Mediterranean is a large almost land-locked water mass separating Europe from Africa and Asia. Partly because of this land-locked nature little research has been undertaken into the physical oceanography and potential fish stocks of the Mediterranean and Aegean regions (Gulland 1971 : 36-39). Amongst Aegean prehistorians the tendency is in fact to see the area as having little fishery potential and characterised by small catches (Gallant 1985 : 40). The Mediterranean and Aegean are admittedly inferior in fish resources to the adjoining Atlantic Ocean but in general the pelagic, demersal and littoral fish are surprisingly diverse and abundant, though dispersed in comparatively low quantities (Rackham and Moody 1996 : 196).

Both the topography and the hydrography of the Mediterranean basin affected the quantity and nature of the Aegean fish catches in antiquity, since the continuity of the water masses in the Mediterranean is broken up by the great variety of land areas in shape, size and mountain systems, some of which have submerged prolongations. For example, a submarine ridge running between Sicily and Cape Bon in Tunisia has a maximum depth of a few hundred metres and divides the Mediterranean into western and eastern parts orientated along a northwest-southwest axis. The Mediterranean has seven deepwater basins that influence the fish stocks, the eastern part that includes Greece, Crete and the Cycladic islands notably having three of the seven. These are:

**The Ionian basin.** This basin has a deepsea floor and a submarine ridge running between western Crete and Cyrenaica separating the Ionian basin from the Levantine basin.

**The Levantine basin.** This deepwater area is located between the Ionian basin and the slope of Asia Minor, the island of Crete separating it from the Aegean region.

**The Aegean region.** This deepwater basin is situated between Crete, the Strait of Dardanelles, the mainland of Greece and Asia Minor. The Aegean basin contains several deeps and troughs, separated partially by rises and ridges.

Except for the Adriatic Sea all the major sub-divisions of the Mediterranean reach great depths. Generally the coasts are rocky and mountainous and the continental shelf steep and narrow.

The hydrological conditions and in particular the water temperatures and salinity levels are important elements in any fishery resource. In the Mediterranean hydrological conditions are dominated by three layers of water, the surface, the intermediate and deepwater masses. In the Mediterranean and the Aegean the thickness of the surface layer varies between 75 and 300 metres, the variable thickness being determined by a minimum temperature at its lower limit. The intermediate layer has a recorded temperature of 14°C and is characterised by temperature and salinity maxima at 400 metres. The deepwater layer occupies the remaining zone with recorded temperatures of 12,9°C at 1000 metres and 13,2°C at 2500 metres (Gulland 1971 : 36). The hydrological conditions in the Mediterranean therefore reveal variations in water depth, layering, salinity and temperature, all factors that have important effects on the potential fish population and subsequent harvesting. Tuna such as the Mediterranean bonito *Sarda sarda* illustrated in Bronze Age art and other varieties of inshore fish identified archaeologically would be found in surface water with summer temperatures of 17-20°C (Laevastu and Rosa 1963 :1847, Fig. 10), whereas the pilchards and anchovy would be caught in colder water probably associated with the deepwater basins (Smith 1949 : 92). Thus the source and direction of water entering the Mediterranean greatly influences the potential fish stocks. The Atlantic water entering the Mediterranean flows mainly along the African coast, reaching the eastern Mediterranean through the straits between Crete and the African coast. These waters then follow the coast of the Levant in a cyclonic route and in the vicinity of Rhodes the water mass enters the Aegean Sea.

The quantity of surface water entering the Mediterranean through the Straits of Gibraltar has been calculated to be some 1 750 000 cubic metres per second, and the outflow 1 680 000 cubic metres per second (Sverdrup *et al.* 1942 : 1077).

Nutrients in the form of inorganic and organic matter are important for the growth of both fauna and flora in any water mass. These nutrients in the Mediterranean are generally scarce and decrease in concentration eastwards. Various factors do however contribute to increase the nutrient content of the Mediterranean, the annual flooding of the Nile between August and September in particular transporting amounts of suspended particles into the Mediterranean. The total inorganic and organic matter transported prior to the construction of the Aswan dam was calculated at 4 kg per cubic metre of water (Gulland 1971 : 37). In the Aegean the concentrations of nutrients are relatively low, due to factors such as sporadic run-off, bad drainage, inadequate mixing and limited biological regeneration of the nutrient material. During

years of high inflow of intermediate water in the Aegean the nutrient concentration increases (Buljan 1953 : 3-62, *cited* Gulland 1971 : 37) and this could influence potential seasonal fish catches.

Fish stocks require an adequate source of food and to sustain and retain them in a particular area supplies of phyto- and zooplankton are essential. In the Mediterranean and the Aegean the production of phytoplankton varies in the different sub-divisions ranging from 7 to 157 mg per cubic metre per 24 hours (Gulland 1971 : 38). The lowest phytoplankton production values were recorded in the Ionian Sea off the Levant and in the Adriatic. Data for phytoplankton in the upper layer of water where the bulk of fishing takes place indicates that in the Mediterranean the highest concentrations of phytoplankton are to be found where the Atlantic water is present, that is at the Straits of Gibraltar and along the coast of Algeria. Intermediate values are to be found off Tunisia and low values are recorded for the Ionian, Levantine and Tyrrhenian waters. With regard to the level of zooplankton in the Mediterranean comparative studies show that the western Mediterranean produces less zooplankton than the northwest Atlantic and Indian Oceans (Gilat *et al* 1965 : 56). A spring peak of zooplankton abundance has however been recorded between March and May in different sub-divisions of the Mediterranean.

Apart from specific water temperature, salinity and nutrient requirements as well as the presence of adequate phyto- and zooplankton fish are attracted to standing crops of seaweed and other marine flora. The data available indicates that the standing crop of benthos in the Mediterranean and the Aegean is relatively low. Comparative benthos values recorded give the Black Sea a range of 50-300 gram/square metre, the eastern Mediterranean 0,3-19 gram/square metre and the Aegean 1,5-5 gram/square metre (Gulland 1971 : 38).

The physical and biological characteristics of the Mediterranean and the Aegean do however support a good variety of fish species which are primarily related to fish of the sub-tropical Atlantic, these fish having originally gained access to the Mediterranean through the Straits of Gibraltar. Some of these fish such as the pelagic pilchards and tuna according to the United Nations Food and Agriculture Organisation, Rome, are of considerable nutritional and commercial importance to the region.

The fishing patterns in the Mediterranean are to some extent pre-determined by the topography and hydrography of the different sub-divisions mentioned earlier, specific fish species in some instances being confined to particular geographical areas. The sprat *Clupea sprattus* for example is only caught in the northern part of the Mediterranean. Similarly some twenty-five species of Red Sea fish occur only in the eastern Mediterranean and are not caught west of the island of Crete. These regional differences are perpetuated in the availability of important species such as pilchard, anchovy, bonito and mackerel which are caught in the northwest Mediterranean (Gulland 1971 : 39). In the southeast Mediterranean *Sardinella*, Atlantic little tuna, frigate tuna and the mackerel *Scomber japonicus* are the predominant pelagic species. Two fish which are both desirable eating and of commercial importance, the hake and the red mullet, are fortuitously found in both the eastern and the western Mediterranean. The Mediterranean and Aegean fisheries today remain essentially small-scale and scattered, the majority of boats being owned and operated by the fishermen themselves, a pattern of fishing reminiscent of the Bronze Age which is encouraged today by the popularity and high prices obtained for fresh fish. Catch statistics are generally unreliable partly because they are based on Greek tax returns which generally under-estimate the catches.

Approximately half the present day Mediterranean catch is pelagic fish which amounts to 76 000 tons (Gulland 1971 : 39). *Sardinella aurita* and *S. maderensis* are caught in the southern and south-eastern regions of the Mediterranean with smaller catches being made in the Aegean. Surprisingly bluefin tuna *Thunnus thynnus*, the bones of which are present in Bronze Age archaeological excavations and a species that is now depleted world-wide, are still caught on their migration route from the Atlantic to the Mediterranean (Tragakis, pers. comm.). Similarly the Mediterranean bonito *Sarda sarda* also present in the archaeological record is still caught and remains of commercial importance. The little tuna *Euthymus alletteratus* and the frigate tuna *Auxis thazard* are caught in quantity in the warmer surface waters. The mackerels *Scomber scomber* and *Scomber japonicus* are caught commercially in the Mediterranean by purse-seiners. Horse mackerel *Trachurus trachurus*, present in the faunal remains from the Minoan settlement at Palaikastro today represents an annual commercial catch of 15000 tons (Gulland 1971 : 39).

*Seriola dumerili* or amberjack, also present archaeologically, is an excellent eating fish which reaches 1,5 metres in length and is common in the Mediterranean. The dolphin fish *Coryphaena hippurus*, again recorded in the Bronze Age, is another species that remains of some

commercial importance in the Mediterranean. Six species of mullet including *Mugil cephalus*, represented in Minoan strata, occur in the Mediterranean and Black Sea. They too remain of considerable economic importance and are caught mainly in estuaries. Shark remains are present in the archaeological records from Saliagos and Lerna (Tables 22 and 23). They are still of minor importance and are represented by the larger Mediterranean species *Carcharias glaucus*, *Oxyrinhus glaucus* and *Carcharodon carcharius* and the smaller demersal *Mustelus* and *Acanthias* species.

Table 17 published by the United Nations Food and Agriculture Organisation (FAO), Rome, contains the catches of fish and crustacea in the Mediterranean for the period 1963 to 1969.

TABLE 17

Fish catches in the Mediterranean and Black Sea:  
By groups of species and by species ('000 metric tons)

<u>Group of species</u> Species	1963	1964	1965	1966	1967	1968	1969
Shads	25,0	52,0	83,0	96,0	89,0	60,0	12,0
Flatfishes	10,0	12,0	13,0	11,0	10,0	10,0	11,0
Sole (common)	5,0	4,0	6,1	4,9	4,0	4,1	4,0
Gadoids	26,0	30,0	27,0	28,0	28,0	31,0	32,0
Hake (European)	13,9	14,4	14,9	15,3	15,1	15,6	17,0
Redfishes, basses, congers, etc	93,0	147,0	145,0	150,0	136,0	127,0	113,0
Jacks, mullets, etc.	80,0	63,0	56,0	60,0	87,0	73,0	69,0
Horse mackerels	50,5	38,1	28,5	24,8	45,6	35,4	28,8
Mullet	10,2	11,8	11,7	12,2	17,5	15,4	15,5
Clupeoids	333,0	353,0	340,0	383,0	394,0	404,0	345,0
Anchovy (North Atlantic)	205,9	209,5	206,7	240,5	263,9	263,8	196,0
Pilchard (European)	112,0	128,0	118,0	131,9	120,0	130,0	136,0*
Tunas, bonitos, skipjacks	29,0	24,0	38,0	33,0	60,0	40,0	72,0
Bluefin tunas	3,9	5,9	5,5	5,5	11,4	8,2	10,0
Atlantic bonito	20,5	14,1	27,3	22,0	41,1	25,3	55,0
Mackerels, etc.	40,0	33,0	36,0	28,0	28,0	30,0	27,0
European mackerel	30,8	28,0	27,8	23,6	20,6	22,7	23,0
Sharks, rays, chimaeras	11,0	11,0	15,0	15,0	23,0	19,0	16,0
Unsorted and unidentified fishes	87,0	83,0	85,0	106,0	126,0	120,0	128,0*
Crustaceans	31,0	35,0	32,0	30,0	36,0	32,0	31,0
Molluscs	92,0	96,0	102,0	86,0	100,0	94,0	94,0

\* Aggregates of which more than 10% was estimated by FAO.

Source: Gulland 1971 : 42

The fish species and catch tonnages listed above confirm that, notwithstanding physical and biological oceanographic characteristics that are inferior to the adjoining Atlantic Ocean, the Mediterranean supports a comprehensive range of pelagic and demersal fish. These closely relate to fish of the sub-tropical Atlantic. Some demersal species such as the dolphin fish and amberjack, as well as the bulk of inshore littoral fish, are excluded from the table because of a lack of accurate catch figures.

Table 17 demonstrates that the fish catches in the Mediterranean remained surprisingly consistent between 1963 and 1969. This suggests that catches were made by small-scale fishermen operating out of harbours close to the fishing grounds, not too dissimilar to the practice followed by their Bronze Age predecessors. The consistency in the catches indicates that harvesting of the fishery resource was well within its sustainable yield. Bluefin tuna however shows a marked rise in exploitation between 1963 and 1969 and it is noteworthy that catches of the Atlantic Bluefin tuna are now prohibited by the International Tuna Commission.

Total fish catches for Greece have increased from 115000 tonnes in 1985 to 140000 tonnes in 1990 (Karakoltsidis *et al* 1995 : 259-260).

This survey of the fishery potential of the Mediterranean and Aegean shows that notwithstanding the near landlocked nature of the Mediterranean, and providing that fish species are not over-exploited, the Aegean offers a useful multi-species fishery. In the past, as today, this resource has contributed appreciably to the food supply and nutrition of the islands and coastal communities.

## 6.2 Sources, interpretation and validity of evidence for fishing in the ancient Aegean

Earlier publications on fishing in the prehistoric Aegean contain information obtained mainly from literary sources, in particular the writings of classical authors such as Aristotle, Athenaeus, Oppian, Plutarch, Pliny, Strabo, Aelian and others. William Ratcliffe's publication 'Fishing from the Earliest Times' (1921) is one example of this kind of scholarly work. Ratcliffe's very readable book (republished in 1969) not only has merit of being written by an Oxford classicist, but has the added advantage of being compiled by a scholar who was an enthusiastic and knowledgeable amateur fisherman. Gallant (1985) in his analysis of the productivity of fishing in the ancient world makes frequent use of Ratcliffe's comments on ancient fishing techniques and technology.

Publications on ancient fishing recognise the important contribution to diet and nutrition that fishing made in the Bronze Age and later classical periods. Rostovtzeff (1941 : 1254) emphasised that fish preserved by drying, salting or pickling was an important component of the diet of the ancient Greeks. Other authors suggest that after cereals, fish was the most important element in pre- or proto-historic diets (Michell 1957; Roebuck 1959; Hopper 1979; Boardman 1980). The importance of fish as a primary dietary component and fishing as a key element of the Aegean economy has however been questioned (Cartledge 1979 : 182; Halstead 1981a : 199-200; Gallant 1985 : 43-44). Gallant argues that ancient literary sources provide a poor source of evidence to define the role of fish in ancient diets. His criticism is based mainly on the fact that the classical references used to support fishing as an economic activity are usually descriptive or anecdotal, hence qualitative rather than quantitative. He writes critically that many of the reconstructions of fish catches and fish as a dietary component draw on the comic authors, a source that he finds an unreliable genre.

In his publication on fishing in the ancient world Gallant (1985) integrates classical sources on fish and fishing into a wider more technically orientated framework. This approach includes a useful list of Mediterranean fish species and catches, comparative information on nineteenth century Adriatic fisheries as well as further comparative material derived from a study of modern peasant fishermen in Malaysia whose fishery, expertise and techniques he suggests resemble those of Greek fishermen of the proto-historic period. However, apart from sketches of nets and fishing techniques and one or two illustrations of fish obtained from classical pottery, the

publication is seriously flawed by the absence of any attempt to integrate into the text archaeological evidence for fishing in the Bronze Age, the period that preceded that of the classical writers. Furthermore there is no relevant geographical and environmental evidence that indicates the preference in the Aegean and Greece for maritime settlements, with their associated lifestyle.

With regard to this preference for coastal settlements McDonald and Hope Simpson (1972 : 131) in their archaeological survey of Messenia argue strongly for a way of life orientated to seafaring and fishing. They emphasise that thirty-one per cent of Early Bronze Age settlements located in Messenia are situated on the coast, frequently at river mouths or within a kilometre of the present coast. Forty-five per cent of settlements are within five kilometres or an hours walk from the sea (*ibid* : 131). Weinberg (1965 : 287, *cited* Angel 1971 : 25) states that a high percentage of settlements of the Greek Neolithic period are also situated near the coast or accessible to the sea. Similarly on Crete the majority of the more important Minoan settlements, proto-palaces or palaces, for example Knossos, Mallia, Kato Zakro, Palaikastro and Gournia are either situated on the coast or else are within some 5 km of the coast.

Apart from geographical and environmental factors and consideration of how they might influence a maritime economy and marine-based diet, there is a small but important body of archaeological evidence in the form of fish faunal remains from prehistoric catches (Evans and Renfrew 1968 : 78-80, 118-121; Gejvall 1969 : 49,50; Von den Driesch 1987 : 1-21; Hinz 1979; Panagiotaki 1993 : 55 and Mylona 1994, Appendices I-III). The identification of the fish species in the diverse prehistoric Aegean catches is enlightening, both with regard to the many different kinds of fish utilised for food and in some instances the surprisingly large catches made, bearing in mind the current trend to criticise the labour-intensive catching techniques used (Gallant 1985 : 29-31).

With regard to the size of catches in the Neolithic and Bronze Age it is pertinent that ninety-seven per cent of the fish bones identified at the Middle Neolithic proto-urban settlement of Saliagos near Antiparos were large tuna (Evans and Renfrew 1968 : 118). This evidence for catches of tuna in antiquity is confirmed by the remains recovered at the Franchthi cave in the Argolid, mentioned earlier. The recent publication of an original and unpublished photograph from Sir Arthur Evans' notes of the Temple Repositories at Knossos (Ashmolean Photographic

Archives 155) also shows what could be large tuna vertebrae, but the identification requires confirmation (Panagiotaki 1993 : 49-91). Tuna make desirable eating and can weigh five hundred kilograms and measure up to 4,5 metres (Smith 1949 : 298).

The recovery of prehistoric fish remains constitutes a possible source of evidence for fishing in antiquity, providing information on the nature and size of catches. The species composition of catches at prehistoric settlement sites in Crete, in the Cyclades and in Greece will be analysed in detail later.

Another useful source of information on fish species and a possible guide to the quantities of certain fish caught by individual fishermen in the Bronze Age are the frescoes recovered at Knossos on Crete, Akrotiri on Santorini and Phylakopi on Melos (Powell 1992 : 307-316, 1995 : 76-79). Over the Queen's Megaron in the domestic quarter of the palace at Knossos was a marine fresco predominantly of dolphins, but also containing fish amongst which flying fish can be identified (Pendlebury 1939, Pl. XXV.2). Other flying fish appear on a fresco from Phylakopi on Melos (Higgins 1967 : 100). Flying fish belonging to the family *Exocoetidae* make good eating. Large numbers of flying fish are netted in different parts of the world and many are caught at night since they are attracted to lights hung over the water. The frescoes at Knossos and Phylakopi containing flying fish suggest that the Aegean islanders saw these fish as part of the general seascape and surely a source of food that would not be neglected.

Two frescoes illustrating fish of archaeological value were recovered by Marinatos at Akrotiri on Santorini (Doumas 1980 : 27,28). The fishermen and their catches depicted on these frescoes are accurate enough for the species to be identified, and the number of fish carried by the fishermen gives some idea of individual catch rates, unless the size of the catch was exaggerated for some reason. One fresco shows an Aegean Bronze Age fisherman holding a catch of twelve dolphin fish *Coryphaena hippurus*. The identification is confirmed as the dolphin fish is the only species in the Mediterranean with that size, head shape and fin configuration (PC Heemstra, JLB Smith Institute of Ichthyology pers. comm.). The smooth rounded profile of the fish resembles the mammalian dolphin, hence the common name dolphin fish. The scientific name *Coryphaena hippurus* describes the helmet-shaped head and tail that is reminiscent of a horse's tail (Van der Elst 1981 : 163). The fresco painter on Santorini not only reproduced the shape and features accurately, but also captured the brilliant colours of a living fish. Live specimens of this elongate

compressed fish are predominantly metallic blue-green in colour often with orange or golden flecks and blotches. Trauma causes marked changes in colour, silvery-blue denoting a feeding phase and yellow (a predominant colour in the fresco fish) stress or capture shock (*ibid* : 163). In the context of the dozen dolphin fish carried in two bunches by the Akrotiri fisherman it is noteworthy that *Coryphaena hippurus* has an exceptionally high growth rate and makes good eating. The two large bunches of dolphin fish illustrated in the fresco, allied to the prolific breeding habits of these fish, may go some small way towards dispelling the notion of poor catches in antiquity. Complementing the Akrotiri fresco is a miniature dolphin fish carved from wood found at Mycenae. The identification is again confirmed by the steeply-profiled forehead and elongate body unique to dolphin fish (Schliemann 1878 : 129).

The second fresco from Akrotiri illustrating fish catches though less clear due to surface damage, shows a catch of three Mediterranean bonito *Sarda sarda* (Bloch 1793; CK Simmonds, Fishing Industry Research Institute, Cape Town pers. comm.). This fish has a close Atlantic relative *Sarda orientalis* and is a smaller member of the tuna family that comprises some fourteen different species. The world angling record for a bonito of 10,65 kilograms provides some idea of the food value of these fish (Van der Elst 1981 : 272). Along the upper sides of the body are between five and eleven oblique stripes which characterise the fish shown in the fresco. Despite being an oceanic fish bonito are frequently encountered near land, small fish and squid being included in their diet. These factors would have contributed to bonito being caught by the fishermen of Minoan Crete and the Cyclades.

The catch of Mediterranean bonito, taken together with the evidence for catches of dolphin fish, provides evidence for a reasonable level of fishing expertise in the Aegean Bronze Age.

Ornaments of fish in bronze, gold and faience offer further opportunities for species identification of fish that were familiar to the fishermen and townsfolk of the Aegean Bronze Age. Pendlebury (1939, Pl. XXVIII.3) illustrates a beautifully made miniature of a flying fish in faience. This find from the palace of Knossos came originally from the Temple Repositories and formed part of the Middle Minoan III collection of objects recently published (Panagiotaki 1993 : 69). A beautiful gold fish ornament also found at Knossos may represent the profile of a fish of the *Carangidae* family (Platon 1970, Pl. 52). These commercially important fish vary greatly in

shape, colour and size and include both the large robust king fishes and the more elongate mackerel-shaped queen fishes.

Schliemann recovered many small gold artefacts at Mycenae and included amongst these are two collections of small gold plates numbering eighty objects that carry the octopus motif. There is also a gold plate decorated with a striking octopus design as well as another ornamental gold object carrying an equally striking octopus illustration (Schliemann 1878 : 181, 268, 166, 109). *Octopus vulgaris* is highly prized in the Aegean and is especially useful as it can easily be preserved by drying in the sun. It could have been taken using a trident either made of bronze or tipped with obsidian (Evans and Renfrew 1968 : 79).

The vase painters of the Late Minoan IB period became particularly interested in the life of the sea including especially the octopus and the nautilus but also ordinary fish, cuttlefish, starfish and various shells, rock formations and so forth. The flexible shape of the octopus was able to fit any surface and was endlessly adaptable for different vessels. Two of the most spectacular examples, said to be by the same hand, were the gourd-shaped flask found at Palaikastro (Bosanquet, BSA Supplementary Paper No. 1, 1923 : 47-48) and a three-handled stirrup vase from Gournia (Boyd-Hawes 1908, Plate H). They suggest a great familiarity with the octopus both as an object of beauty and an important food item. Mountjoy (1984 : 161ff) identifies 23 different Marine Style vessel shapes, and records instances of the spread of the style throughout the Aegean and beyond, attesting its general popularity.

Fish hooks, a lead sinker and net weights recovered from Gournia (Boyd-Hawes 1908 : 35) and Ayia Photia (Davaras 1971 : 392-397) on Crete provide evidence for line fishing and the use of nets, two techniques that still form the basis of the Aegean fishing industry. Ratcliffe (1921 : 238) illustrates two Aegean barbed Bronze Age fish hooks, described as Mycenaean, located in the British Museum, London. These finds of fishing hooks demonstrate that line fishing was practised on Crete from as early as Early Minoan II. Warren has suggested that the perforated stone weights recovered at Myrtos, dated by their archaeological context to c. 2200 BC, were possibly used as net weights (Warren 1972 : 216).

The sources of evidence for fishing in the Aegean Bronze Age are mainly archaeological. The illustrations of fishing related topics on Bronze Age frescoes, pottery and other artefacts can perhaps best be seen as useful additional evidence.

Apart from academic argument on the interpretation and validity of the evidence for ancient fishing, the economic role and fishing skills of the Aegean Bronze Age fisherman have been examined. The Aegean fisherman is generally perceived as a rather lowly member of the community owning few possessions and using inadequate techniques to harvest a rather meagre Mediterranean fishery resource, the fish that he caught playing only a supplementary role in the economy and food supply of his community (Gallant 1985 : 43). Primarily on the literary evidence fish are seen as a food commodity of the poorer classes, rather than a dish that graced the tables of the more affluent people. The illustrations that we have showing Aegean Bronze Age fishermen tend to support this view. Fishermen are depicted as lowly but physically fit individuals working either naked, as seen in the Akrotiri frescoes (Doumas 1980 : 27-28), or else wearing only a loin cloth as illustrated on the Fishermen vase recovered from Phylakopi on Melos (Ratcliffe 1921 : 62). The two frescoes and the vase painting show the working wear of an Aegean Bronze Age fisherman c.1500 BC. It is important, however, not to equate this lowly status with a lack of expertise and specialised knowledge. As the archaeological evidence discussed earlier indicates the Minoan fisherman had access to two major components of any modern fishing industry, a range of barbed hooks and weighted fishing nets. To these important assets he contributed specialised knowledge of the marine environment and its fish.

In the earlier part of the century the Homeric epics were studied in an attempt to throw light on the capture and consumption of fish in the Bronze Age (Ratcliffe 1921 : 63-69; Seymour 1907, *cited* Ratcliffe). Although these works deal with the Late Bronze Age, the subject matter is considered to have only been written down c. 700 BC, and this has rightly caused doubts as to the admissibility of the material as reliable evidence of Bronze Age practices (Forsdyke 1956 : 7). Accurate observation of the life and manners of the past is, however, a phenomenon peculiar to Greek epic (*ibid* : 17) and the real contribution of Homer to history lies in details of contemporary life (*ibid* : 27). Sherratt (1990 : 807) has pointed out that detailed descriptions essential to the plot are less susceptible to change than other elements, related to the needs and expectations of the audience. It would seem possible that, while the Homeric bards were using fish similes accessible to their Classical Greek audiences, evidence for fishing goes so far back to

the Bronze Age and beyond and these metaphors could well have been sourced to the earlier period - this could be a point where literature and archaeology meet.

The evidence that emerges is somewhat paradoxical as although references to the consumption of fish are few, both the Iliad and the Odyssey draw considerable attention to catching methods and gear. As a consequence of the few references to fish as food, scholars have tended to relegate it to a position of a second rate foodstuff or more suited to the poorer classes (Gallant 1985 : 42). This downgrading appears to be mainly related to the absence of fish (together with poultry, fruit or vegetables) in Homeric descriptions of celebrations and banquets; only in connection with starving are they mentioned (Ratcliffe 1921 : 69).

Passages in the epics, however, indicate that the role of the fisherman and the value of his catch were indeed recognised and esteemed.

In Odyssey XIX.111 we get a description of the well-ordered realm of a 'blameless King' in which fish are an important food component:

"the black earth bears wheat and barley and trees are laden with fruit  
and sheep bring forth and fail not and the sea gives store of fish".

This descriptive passage reveals that in the Homeric Late Bronze Age fishermen had an important role in the community amongst the coastal and island dwellers of the Aegean. The food value of their fish furthermore was equated with that of cereals, fruit and pastoralism.

The collection of oysters is another maritime activity referred to in the Iliad (XVI.746).

"This man would satisfy many by searching for oysters".

This is possibly the only mention of oysters for human consumption in the Homeric poems. One suggestion is that oysters provided food for the ship's crew. Oyster shells were also recovered from one of the Late Bronze Age Shaft Graves at Mycenae (Schliemann 1878 : 332), the shells being found in association with artefacts such as a gold funerary mask, jewellery and the skeletal remains of three people.

As previously mentioned the number of Homeric descriptions of fishing techniques in the Iliad and Odyssey contrast with the few references to fish as food. The examples that follow describe fishing with a trident, the use of nets and fishing with a rod or hand-line. Nearly all these Homeric references to fishing function as similes. The assumption is that Homer's audience had a knowledge of traditional Aegean fishing methods as techniques had changed very little over thousands of years.

Odyssey X.124 reveals that the fishing trident was used in the Aegean Bronze Age. The simile describes Odysseus' crew being speared like fish by the Laestrygones after their boats had been destroyed. Note: All translations from The Odyssey are by Butcher and Lang (London 1881) and those from the Iliad by Lang, Leaf and Myers (London 1883) cited by Ratcliffe (1925).

"And like folk spearing fishes they bore home their hideous meal".

Use of the trident for fishing depends on practised skill and a good knowledge of the local marine fauna; also a marine environment that has shallows and rock pools. Trident fishing is scorned for its low productivity, labour intensiveness and its restriction to surface species of fish (Gallant 1985 : 13). Archaeological finds of obsidian tips from Neolithic Saliagos possibly support Homeric evidence for the use of the trident in the Bronze Age (Evans and Renfrew 1968 : 79). The recovery of cuttlefish remains at Saliagos (Evans and Renfrew 1968 : 80, 137) also indicates that these cephalopods (*Sepioloa officinalis*) were harvested in the Middle Neolithic.

The abundance of cephalopods at Antiparos is confirmed by a catch of 25 tonnes of octopus per annum at the end of the nineteenth century (Tsountas 1898 : 80, cited Renfrew and Evans 1968 : 80).

Jane Renfrew (*ibid* : 74) has suggested that the trident was used for catching tuna at Saliagos, her evidence being based on an absence of fish hooks and that ninety-seven per cent of all fish bones recovered were tuna.

Strabo and Oppian contribute more evidence for the tradition of spear fishing in the Aegean. They describe how large fish were trapped in shore-based nets and then speared; also how fish were lured to boats in open water using a light source or bait (Oppian 3.535, 4.640-646,

5.355, 429-450; Strabo 1.2.16). Homeric, archaeological and later classical evidence thus indicates that fish were caught in the prehistoric Aegean by spearing. Relative to the geomorphology of the marine environment, fish stocks and the skill of the Aegean fisherman there is no reason why considerable quantities of fish or cephalopods were not caught using the leister or spear.

The most popular method of catching fish in the Aegean Bronze Age was probably the hook and line. Archaeological evidence for the use of hook and line is reinforced by literary and iconographic evidence from the later Classical period. Of thirty-five species of fish for which the method of catching is described in literary sources, twenty-eight were caught using hook and line. Of these twenty-eight species of fish fifteen were caught on hook and line only (Gallant 1985 : 14). By the Early Bronze Age the bone fish gorge used instead of hooks by Lower Palaeolithic fishermen had been replaced by bronze hooks as recovered archaeologically at the Minoan coastal village of Gournia, the cemetery at Ayia Photia and elsewhere in the Aegean. Evidence indicates that special hooks were used for the different species of fish. Strong short-shanked rounded hooks were used for catching Mediterranean bonito (*Sarda sarda*) (Davaras 1994 : 10; Ratcliffe 1921 : 238) and also for the grey mullet (*Mugil cephalus*) (Boyd-Hawes 1908 : 35 No. 43; Robinson 1941, Pl. 118). Even stronger long-shanked hooks were used for catching shark (*Squalus acanthias*) and albacore (*Thunnus alalunga*) (Oppian 3.144-146). Unbarbed hooks were used for mackerel (*Scomber scomber*) (Boyd-Hawes 1908 : 34 Nos. 40, 41, 42; Robinson 1941, Pl. 117). The use of unbarbed hooks for mackerel, a smaller seasonal pelagic fish that comes inshore during summer migration to spawn could imply that these fish were caught in quantity simply by hooking, and then skilfully flicking them ashore onto piles. Apart from archaeological evidence for the use of bronze hooks and lead sinkers dating from the Early Bronze Age in the Aegean, the Homeric poems contain the following references to the use of the hook and line in the Aegean Bronze Age which affirm the use of bronze hooks.

"As when a man sits on a jutting rock and drags a sacred fish from the sea with line and glittering hook of bronze, so the bright spear dragged he Thestor."

Iliad XVI 406ff

(the companions of Menelaus) "were ever roaming round the isle fishing with bent hooks, for hunger was gnawing at their belly."

Odyssey IV 368f

(the companions of Odysseus) "went wandering with barbed hooks in quest of game, as needs they must, fishes and fowls, whatever might come to their hand, for hunger gnawed at their belly."

Odyssey XII 330f

The above three passages suggest that fishing was an effective manner of obtaining food.

And finally, in Iliad XXIV 80ff, the description of Iris on her mission to which she was directed by Zeus reads:

"And she sped to the bottom like a weight of lead, that mounted on the horn of a field-ox goeth down, bearing death to the ravenous fishes."

Rod and line fishing and handlining were the two methods of using hook and line in the Aegean Bronze Age. Odyssey XII 251ff contains a description of rod and line fishing, the simile of fish being pulled ashore using rod and line being used to describe Odysseus' crew flung ashore by Scylla.

"Even as when a fisher on some headland lets down with a long rod his baits for a snare to the little fishes below, casting into the deep the horn of an ox of the homestead, and as he catches each flings it writhing ashore, so were they" (the companions of Odysseus) "borne upward to the cliff."

Five explanations are offered for "the horn of an ox" referred to in the last two passages. One is that a little pipe of horn protected the line (which passed through it) just at the junction with the hook, a precaution similar to the use of trace-wire between the line and the hook when fishing for shark. Another suggestion was that the lower line was protected by a hollow piece of horn lest the fish should bite the line. The third suggestion was that a lead weight serving as a sinker was attached to the little tube of horn. A modern parallel is the pike fisherman who has his line bound to prevent the fish biting through it. Another ingenious explanation is that the horn was possibly carved into a small fish that functioned as a spinner, in other words as an artificial bait or lure (Ratcliffe 1921). A further suggestion is that carved ox horn served as a hook (Ackman, pers. comm.).

The fishing line used with a rod in the Aegean in the Classical period was made of horse-hair with single or multiple hooks attached to it (Plutarch, SA 976f; Oppian 3.75 443-481). The relatively weak strength of the horse-hair line and its restricted length placed

limitations both on the size of fish that could be caught and on the distance that the line could be cast. The mention of 'headland' and 'little fishes' in the passage from the Odyssey supports this assumption and indicates that rod and line fishing was restricted to shore or rock angling and the smaller species of fish. In support of the argument for small catches in the Aegean in antiquity, Gallant (1985 : 38) points out that present-day Malaysian fishermen using rod and line average five kilograms or 3,5 fish per day. While accepting criticism that the catch per unit effort would be low, five kilograms of fish provides an adequate protein supply for an extended family.

The Homeric poems and earlier Bronze Age archaeological evidence support the use by Minoan and Aegean fishermen of handlines and barbed hooks in the Bronze Age. Evidence from the Classical period also points to the use of flaxen lines with multiple baited hooks. These lines were probably trawled from small boats, comparable in size to the trek boats used off South African beaches and which offered increased potential for line fishing. The fishing methods described follow present-day practice, and indeed the bulk of fish sold from fish counters or served up in restaurants is line-fish caught in this age-old way.

Later Classical writers substantiate the Homeric evidence for these traditional Aegean fishing methods. Albacore (*Thunnus alalunga*), dolphin fish (*Coryphaena hippurus*), swordfish (*Makaira nigricans*) and skipjack tuna (*Katsuwonus pelamis*) were caught by handlining. This method was also recommended for catching bluefin tuna (*Thunnus thynnus thynnus*) and the Mediterranean bonito (*Sarda sarda*) (Oppian 3.132, 144-146, 175, 280-325, 524, 4.247-250, 5.355; Aelian 14.23, 15.10).

In addition to the Classical writers' recommendations on the use of hooks and lines for certain fish species, both these early writers as well as present-day fishing scientists emphasise the economic importance of the annual age-old Mediterranean tuna migration (Aelian 15.5; Michell 1957; Laevastu and Rosa 1963). The quantity of tuna remains mentioned earlier points to the economic importance of this phenomenon in the Aegean Middle Neolithic and later Bronze Age. Even today the Mediterranean tuna run is of economic importance to islands such as Sicily.

The use of long-lines or stringers in the prehistoric Aegean as an alternative to trolling is suggested by Gallant (1985 : 15, 16). The method entails the use of a long flax rope to which many small lines with hooks are attached at regular intervals along the entire length. If we accept

the Homeric evidence for the use of flax in net-making, long-lining is a possibility for the Aegean Bronze Age. This fishing system is still used by present-day Far Eastern fishermen to catch bluefin (*Thunnus thynnus thynnus*), yellowfin (*Thunnus albacares*) and albacore (*Thunnus alalunga*).

The technique of netting fish is however the only fishing method that enables fishermen to harvest large quantities of fish. Like hooks and lines, netting is an age-old procedure, largely unchanged but with the substitution today of nylon for flax and the use of powerful winches to pull the heavy net aboard the boat. The four primary netting procedures, all of which were probably used by the Aegean Bronze Age fishermen and which are still used in different parts of the world today are hand-cast nets, beach seines, gillnets (roundly condemned today by environmentalists) and tonnara nets, which are used to trap migratory fish such as tuna in semi-enclosed bays. The only archaeological evidence for the use of nets for fishing in the Aegean Bronze Age are the finds of weights discussed earlier. These weights have been tentatively identified as net sinkers, finds of which were made at Gournia (Boyd-Hawes 1908 : 33, No. 41) and Myrtos (Warren 1972 : 216), both coastal villages in eastern Crete dating to approximately 1500 and 2200 BC respectively. Waisted-weights were also recovered at Saliagos (Evans and Renfrew 1968 : 79). Archaeological finds of Bronze Age net weights are substantiated by two references in the Homeric poems, where examples of netting are used as similes. The first relates to Odysseus after the killing of the suitors:

"But he found all the sort of them fallen in their blood in the dust, like fishes that the fishermen have drawn forth in the meshes of the net into a hollow of the beach from out the grey sea, and all the fish, some longing for the salt waves, are heaped up on the sand, and the sun shines forth and takes their life away: so now the woovers lay heaped upon each other."

Odyssey XXII 383ff

Beach seining as described by Homer is practised today and has remained unchanged for many thousands of years. A net fifteen metres or more fitted with floats at the top and weights at the bottom is played out from a boat rowed in a semi-circle from the shore. The two wing-lines are pulled in by the shore-men and the net containing the fish beached. Plutarch (SA 977f), Oppian (3.124, 4.490-503) and Aelian (1.141) all describe beach seining for catches that included red mullet, gilthead bream, black bream, anchovies and the occasional dolphin. Aelian notes that rays were also captured. Of species recorded mullet and anchovy are small shoal fish, whereas

bream winter in deeper water and move inshore in summer. The passage in the Odyssey is a realistic account of beach seining, in particular the description of the fish slowly dying heaped up on the sand in the hot sun.

The following Homeric passage describes the Bronze Age use of flax fishing nets. This literary evidence is supported by archaeological evidence that flax was probably available in the Aegean from the Early Bronze Age, its use probably originating in the Near East as early as 5000 BC (Renfrew 1972 : 269). Flax for net-making has also been recovered in Egypt (Guide to the Egyptian Collections in the British Museum 1969 : 23).

"Only beware lest, as though entangled in the mesh of all ensnaring flax,  
ye be made unto your foeman a prey and a spoil."

Iliad V 487ff

The same passage also points to the use of a second type of net in the Aegean, the entangling all ensnaring gillnet. These gillnets or 'walls of death' are effective and Oppian describes their use for mackerel (*Scomber scomber*), garpike (*Belone belone*) and bluefin tuna (*Thunnus thynnus thynnus*) (3.577-605). Oppian describing 'pelamyd' fishing states that the net extends from the shore and that the fishermen drive the migrating shoalfish towards the net by beating the water with their oars. The fish swim into the net and pressure of the mesh causes the gill covers to spread and the fish are held fast and unable to move forwards or backwards (4.562-592). He remarks that the trapped fish appear as if they were fixed to the net as with nails. Gallant raises the point that to be effective gillnets have to be woven precisely and have a constant mesh size. On this basis and despite the evidence of Oppian, he questions the use of gillnets in the Aegean. It is noteworthy that the faunal record of Bronze age catches recovered at Palaikastro contains both small inshore fish as well as one or two larger off-shore species (Mylona 1994 : Appendix III). This might suggest that the Minoans used woven close-mesh nets that were intended to catch the smaller inshore fish, but which occasionally caught the odd larger fish for example of the *Carangidae* family.

Aelian and Oppian both describe set-net procedures for catching tuna that bear comparison with the true tonnara (Aelian 15.5; Oppian 3.640). These consist of three long pieces of net that are used to seal off a small bay. The first net is secured to the shore and then pulled out into the water at a 90 degree angle to the beach. The second net is set at 90 degrees

to the first or parallel to the shore. These nets together with the beach thus form three sides of a box. The fourth side is left open but a loose piece of net is left in position ready to be pulled onto the beach once fish have entered, this forming the fourth side of the box. The tangled mass of nets with struggling fish is then pulled into the shallows and the fish killed by spearing or clubbing. Jane Renfrew points out that the total catch of *Scombridae* in Greek waters in 1936 was some four hundred tons, only seventy times the amount of tuna recovered from one excavation pit at Saliagos (Evans and Renfrew 1968 : 79). This evidence suggests that in contrast to Gallant's opinion effective techniques were used in the Aegean for catching tuna at an early date. It is possible that tonnara-type nets were used, particularly since the shallow narrow configuration of the bays favoured this kind of fishing.

The fourth type of net which is technically the simplest is the hand-casting net, used in subsistence fisheries throughout the Western world and Far East (Gallant 1985, Pl. 7). This circular net has heavily weighted edges and at least two holding lines. The fisherman again requires considerable skill both at spotting the fish and casting the net, since he must wait until the fish appears and then cast it, the lead weights quickly sinking the net and trapping the fish. Plutarch states that hand-cast nets were used to catch Mediterranean species that included grey mullet (*Mugil cephalus*), rainbow wrasse (*Coris julis*) and seabass (*Epinephelus tauvina*) (Plutarch SA 977e). The technique of hand-casting a net requires only one fisherman and has a correspondingly low level of productivity. The method was certainly used in the Classical period and is still widely used by fishermen both at the coast and on inland waters. There is no evidence for its use in the Aegean Bronze Age, but because of its widespread traditional usage it is probable that the method was used in the Aegean in the Bronze Age.

It is unfortunately not possible on the present evidence to positively relate the various fish faunal remains found at Aegean Bronze Age settlements to the different catching methods and net patterns described in the Iliad and the Odyssey and by later Classical writers. The two most comprehensive inventories of fish faunal remains, those from Saliagos and Palaikastro compound the problem since they differ in fish species, settlement patterns and chronology. Indications from Saliagos are that entrapment and spearing as described by Homer and later writers took place on a seasonal basis, the target fish being the migratory bluefin (*Thunnus thynnus thynnus*) or longfin (*Thunnus alalunga*) tuna. At Palaikastro however small mesh nets were probably used in addition to hook and line to catch mainly the smaller littoral fish.

With the difficulty of correlating and synchronising the archaeological and literary evidence in mind, the question has to be asked as to how valid the Iliad and the Odyssey and the later Classical writers are as admissible evidence for Aegean Bronze Age fishing. I would suggest that their primary value lies in providing invaluable background information and historical depth for the archaeological finds that consist of fish remains, hooks, sinkers and net weights. Notwithstanding that the archaeological material is central to any scientific reconstruction the literary texts provide taxonomic, technical, economic and social additional information. Metaphorically speaking Homer and the later authors put flesh on the dusty fish bones recovered by excavation.

The end of the Cretan Bronze Age, based on evidence from refuge sites such as Karphi, Vokastro and Kavousi, was c. 1100 BC (Pendlebury 1939 : 303). The composition of the Homeric poems probably occurred c. 700 BC, these two events suggesting a time interval of about 400 years. For the later Classical writers such as Oppian, Aelian and Plutarch the time span between the end of Minoan Crete and their writing exceeds a thousand years. In certain disciplines these periods of time could imply major technical changes, but fortunately for fishery researchers fishing is an extremely conservative occupation, with essentially simple techniques used virtually unaltered over many thousands of years. In fishing the introduction of new materials has been of more consequence than actual improvements in technology. Historical markers are the shift to metal hooks from bone fish gorges, the use of flax for fishing lines instead of horse hair and the introduction of flax for nets. The present day has seen the introduction of nylon. These materials have been introduced over a period of some five thousand years. Supporting this conservative approach are the fishermen themselves who adhere strongly to the traditions of their forefathers. The fact that a description of beach-seining in the Odyssey (XXII 383ff) is wholly applicable to present-day trek fishing on the southern South African Cape coast confirms this conservatism. An interval of some thousand years between the end of the Bronze Age and the writing of descriptive material referred to here is therefore of little consequence in the reconstruction of Aegean fishing. Homer's knowledge of the sea and his use of similes taken from traditional fishing practice suggest that both he and his audience were well acquainted with fishery matters. Many of the taxonomic and technical observations of the Classical writers are surprisingly perspicacious. Aristotle's comments on the fecundity of the dolphin fish *Coryphaena hippurus*, for example, almost anticipates the present-day mariculture research into artificially growing this prolific species.

Notwithstanding the paucity of evidence that prevents wider consensus between the archaeological and literary sources there are however some important technical and taxonomic areas of agreement. In both the archaeological material and textual evidence we find consensus on the use of hook and line, as well as points of similarity on the different kinds of nets. Furthermore there is some good correlation between the species found in the fish faunal remains and those recorded in the literature.

The archaeological and literary evidence reviewed indicates that the different species of tuna were important components of the Minoan and Cycladic catches. However before presenting scientific data relating to tuna and other fish species in the Mediterranean and the Aegean, it is necessary to clarify certain collective terms used in connection with fishing. Central to discussion on the Aegean prehistoric fish catches are the terms pelagic and demersal, since they define the scope of a fishery and indicate to what extent catches might have been affected by the seasonal nature of the resource. The term pelagic is applied principally to migratory shoal fish that inhabit the open sea and are caught close to the surface. Pilchard and anchovy are two common examples of pelagic fish (Van der Elst 1981 : 354). Tuna are usually also classified as pelagic fish.

Demersal fish are distinguished collectively by the common characteristic that they live close to the sea bed. In the Aegean the demersal species probably outnumber the pelagic fish and because they were more easily caught from the shore in the Bronze Age, prehistorians suggest that they made up the greater proportion of Aegean catches (Gallant 1985 : 25; Mylona 1994 : Appendix III). The impression gained from certain publications on Aegean fishing that demersal fish species are mainly confined to the inshore zones is incorrect since some of the larger demersal fish, such as the hakes, today form the basis of offshore trawling industries. In the context of Aegean prehistory the term littoral is probably a better description for the many small fish species caught from the shore in the Bronze Age using hook and line or nets.

Taxonomically the pelagic fish comprise three main families, the *Scombridae*, the *Engraulidae* and the *Clupeidae*. Gallant in his publication on the productivity and economic potential of prehistoric Aegean fishing writes that the 'the *scombridae* (mackerels), the *scombormoridae* (pelamyds) and the *thunnidae* (tunnys)' comprised three of the five main groups of fish caught in the region in prehistory (1985: 27). This statement is misleading since tuna and

mackerels are both classified as *scombridae* (Van der Elst 1981 : 267-277). Gallant applies the term pelamyd (*sic*) to the small Mediterranean tuna *Sarda sarda* (Gallant 1985 : 64), which is depicted in an Akrotiri fisherman fresco (Doumas 1980 : 88). The term pelamyde was reportedly first used by Aristotle (HA VIII.15) to describe small tuna that bury themselves close inshore in mud (Ratcliffe 1921 : 101). The Latin transliteration from the Greek (viz. pelamis) is however used today to taxonomically identify the small skipjack tuna *Katsuwonus pelamis*. The bonito *Sarda sarda* and the skipjack *Katsuwonus pelamis* are very similar, and when caught commercially no effort is made to separate or correctly identify the two.

Both in prehistory and today the *Scombroid* family of tunas and mackerels constitute one of the Mediterranean and Aegean's most important fish stocks. Table 18 contains a list of *Scombroid* fish comprising tuna, mackerels and billfish caught in the Mediterranean and Aegean. The table is compiled from Classical and Nineteenth and Twentieth century literary sources.

## PLATE 2

Palaikastro Middle-Late Minoan settlement showing architectural remains and access to the sea for fishing



TABLE 18

Tuna, mackerel and billfish caught in the Mediterranean and Aegean

Species	Habitat	References
Albacore tuna <i>Thunnus alalunga</i> (“longfin tuna”)	Three populations: (a) Ionian Sea, lower Adriatic (b) Aegean, breeds off W. Crete (c) N. Aegean - Sea of Marmora	Aelian 13.17 Aristotle HA 570b 20 Athenaeus V.c6, VII.c63, c137 Laevastu & Rosa 1963:8 Evans & Renfrew 1968:118
Bluefin tuna <i>Thunnus thynnus</i> <i>thynnus</i>	Three populations: (a) Western Mediterranean (b) Central Mediterranean (c) Eastern Mediterranean	Aelian 13.16, 15.5 Oppian 3.132, 336, 281, 337, 630-48, 4.562 Laevastu & Rosa 1963:4 Evans & Renfrew 1968:118 Gulland 1971:39,42
Mediterranean bonito <i>Sarda sarda</i>	Number of populations in Mediterranean; great economic importance.	Aristotle HA 488, a6 Atheneus 278b Plutarch SA 977a Oppian 1.112 3-144 Laevastu & Rosa 1963:10 Gulland 1971:39, 42 Doumas 1980:44, No.27
Frigate mackerel <i>Aucis thazard</i>	Numerous populations in Mediterranean. Move inshore June-July. Found in small groups.	Faber 1883:198 Laevastu & Rosa 1963:11 Gulland 1971:39, 42
Skipjack tuna <i>Katsuwonus pelamis</i>	Eastern Mediterranean, Aegean	Aristotle HA 488 a6, 543 a2 Plutarch SA 980a Aelian 15.10 Oppian 4.540-92 Laevastu & Rosa 1963:9
Little tuna <i>Euthynnus alletteratus</i>	Numerous populations in Mediterranean, east and west	Laevastu & Rosa 1963:7 Gulland 1971:39, 42
Spanish mackerel <i>Scomber japonicus</i>	Number of populations in Mediterranean. Bi-annual seasonal migrations.	Aelian 10.6 Faber 1883:106, 161 Gulland 1971:39, 42
Mackerel <i>Scomber scomber</i>	Four populations in Mediterranean/Black Sea. Bi-annual seasonal migrations. Inshore during spawning.	Faber 1883:32-33, 77, 106, 159, 151, 161 Gulland 1971:39, 42
Swordfish <i>Xiphias gladius</i>	Caught in some quantity	Gulland 1971: 39

The information contained in Table 18 suggests that the harvesting of *Scombroid* fish viz. the tunas and mackerels as well as swordfish was a traditional Mediterranean activity extending back to the proto-historic period and earlier. Comparison of Tables 18, 19, 22, 23 and 24 shows that albacore, bluefin, bonito and skipjack tuna as well as mackerel are generally common to the Homeric and Classical sources, the archaeological record and recent scientific publications. Comparison of this old and new evidence for Mediterranean and Aegean fishing suggests that the populations of *Scombroid* fishes have not altered appreciably since the Bronze Age, and still constitute an important food source for the region's people. These findings are generally confirmed by personal inspection of the fishing harbours and fish markets at Siteia and Ayios Nikolaos in eastern Crete.

All the *Scombroid* fishes are powerful swimmers with torpedo-shaped bodies and pointed snouts, tapered tails and strong forked caudal fins and the larger Atlantic tunas such as bluefin and albacore undertake wide-ranging migrations. This migratory behaviour and unpredictability of their seasonal arrival in the Aegean is used as an argument in favour of poor tuna catches in antiquity (Gallant 1985 : 30). However it can be accepted that reasonable catches of the different tuna were made in the Classical and preceding Bronze Age period. In addition to the Bronze Age archaeological evidence, the literary evidence that supports this is based on further descriptions of tuna fishing by Aristophanes, Pliny, Aelian and Aeschylus. Aristophanes (Hipp. 313) compares Cleon to a watcher posted on a cliff to signal the approach of a shoal of tuna. Aelian (Nat. An XV.5) provides a description of a tuna fishing lookout tower that was made from wooden cross-pieces suspended between two fir trees. Both Pliny and Aeschylus use images based on tuna catching to provide dramatic pictures that their audiences are familiar with. Pliny (IX.2) describes a tuna shoal so large that the boats of Alexander had to advance in battle formation to progress through the great mass of fish. Aeschylus (Persae 434ff) uses a description of tuna being speared to provide a vivid image of the destruction of Xerxes' fleet by the Greeks. He describes the Greeks hacking and striking at the enemy with bits of broken oar and splintered planks just as if they were spearing tuna. This literary evidence for tuna fishing from the Classical period supports the evidence in Tables 18, 22 and 23. The large body of literary, archaeological and scientific evidence for tuna fishing in antiquity in the Aegean tends to swamp the suggestion that the erratic seasonality of tuna migration would negate attempts by Bronze Age and later Classical fishermen to catch them.

It can be argued that the most important single factor that determined the size of the Aegean Bronze Age tuna catches was not the migratory habits of the fish nor the available expertise of the fishermen but sea temperature. Migrating tuna swim along the edges of warm water thermoclines. Figure 13 shows the optimum temperature range for the bonito, bluefin, skipjack, albacore and little tuna that are caught in the Mediterranean and Aegean.

FIGURE 13  
Temperature spectra for tunas  
(Laevastu and Rosa 1963, Fig. 10)

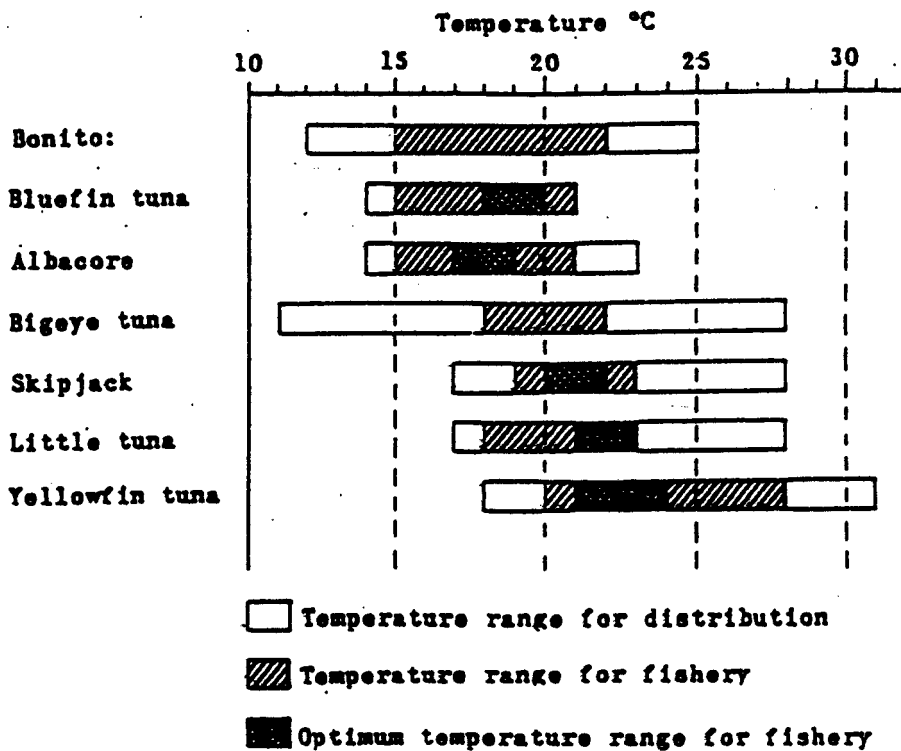


Figure 13 reveals that the two important tuna caught in the Aegean Bronze Age, bluefin and albacore, are temperate water species with optimum water temperature ranges of 18 to 20°C and 16 to 18°C respectively. These temperature ranges indicate that the fish would be caught in the Aegean in summer, and in particular in August when a 20°C isotherm approaches the entrance to the Mediterranean from the Atlantic. A lesser 15°C isotherm is present in February (see Laevastu and Rosa 1963, Fig. 11). The highest concentrations of bluefin and albacore would probably be found in the region where the optimum temperature zone is narrowest.

Figure 14 shows the distribution of fishing areas for bluefin tuna.

FIGURE 14

Distribution and fishing areas for bluefin tuna *Thunnus thynnus thynnus*  
(Laevastu and Rosa 1963, Fig. 1)

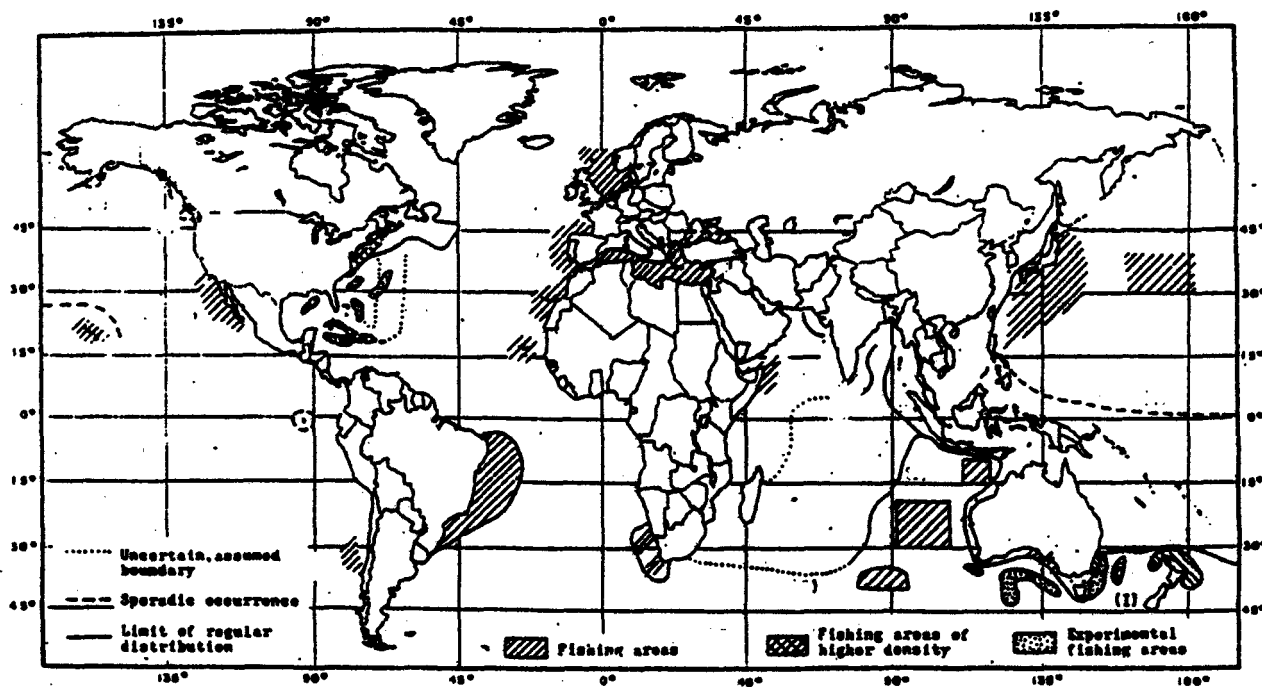


Figure 14 shows that as late as 1963 the Mediterranean and Aegean were still good commercial fishing areas for bluefin tuna, this strongly supporting the archaeological and literary evidence presented for tuna fishing in antiquity. The distribution data refutes the assumption that bluefin tuna was probably the most overrated food fish in the Mediterranean in antiquity, having a high prestige value but caught in relatively small numbers.

Albacore tuna (*Thunnus alalunga*) comprises about ten per cent of the world's tuna resource and because of its delicate white flesh is a much sought after marine food. Albacore is one of the most widespread of the tuna species and occurs mainly between the equator and 40° South, as well as in the Mediterranean, Aegean and off Spain.

Figure 15 shows the distribution and fishing areas for albacore.

FIGURE 15  
Distribution and fishing areas of albacore *Thunnus alalunga*  
(Laevastu and Rosa 1963, Fig. 5)

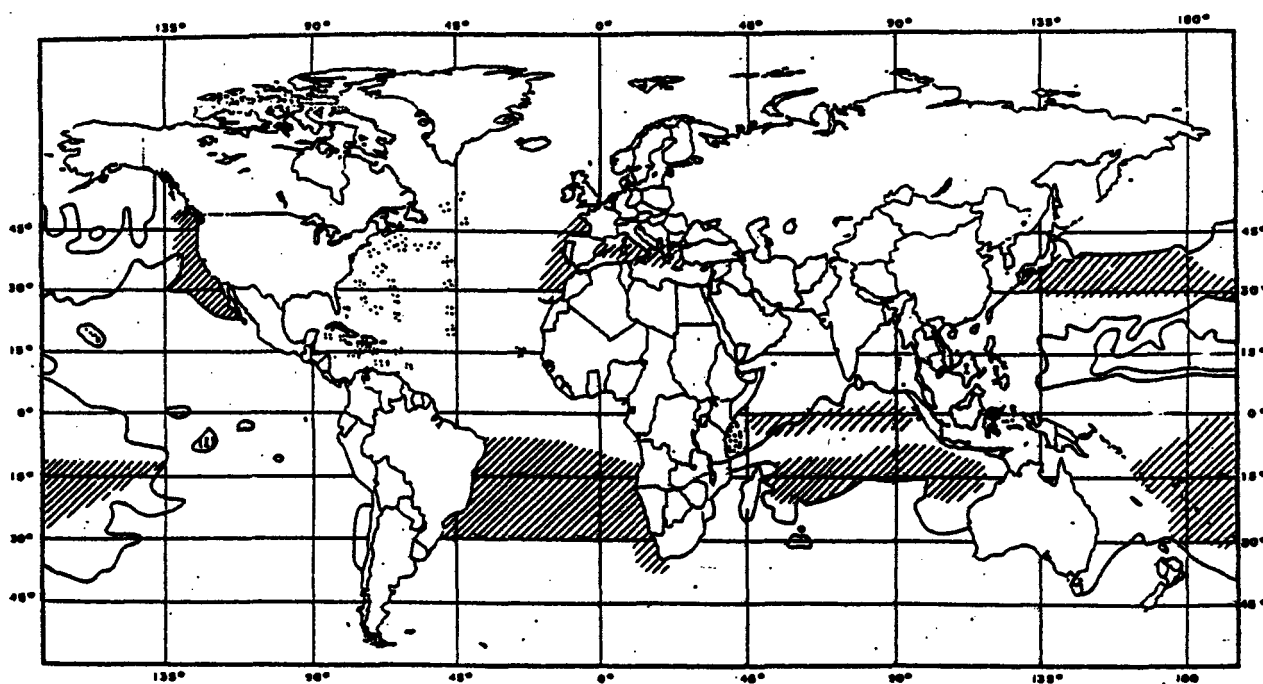
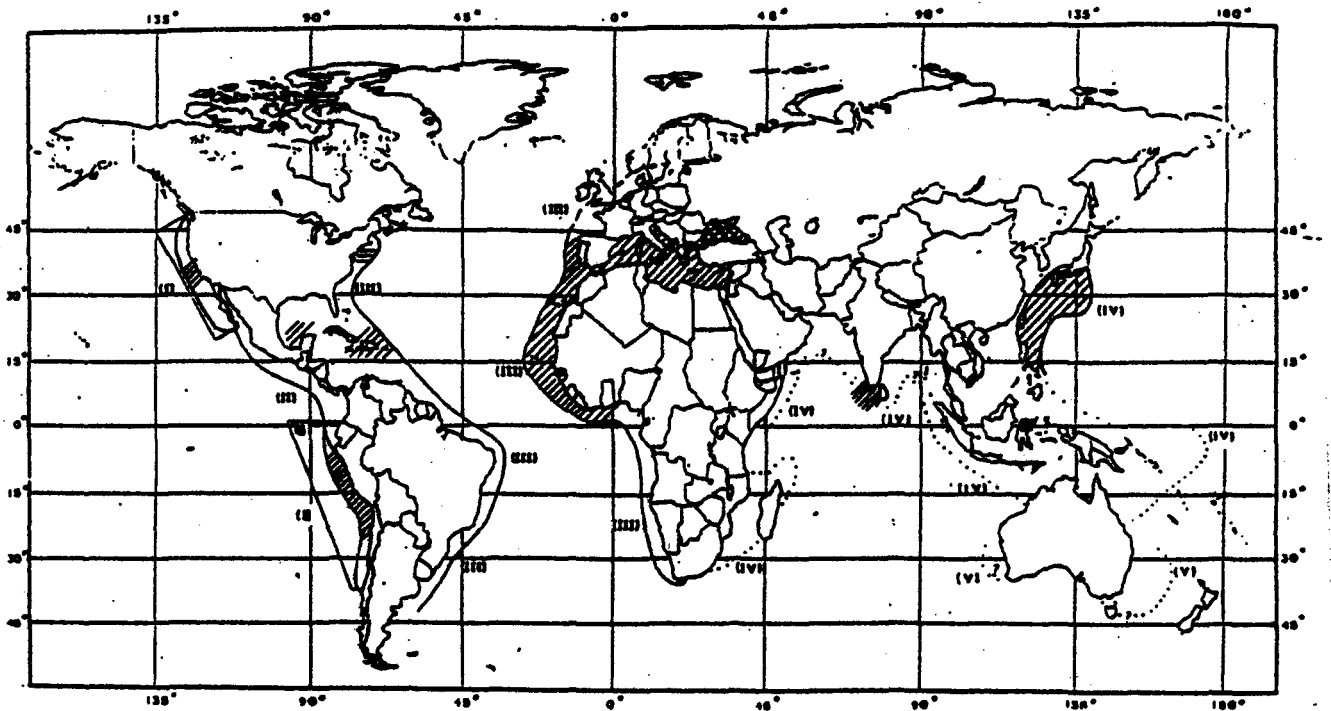


Figure 15 reveals an albacore stock in the Aegean and off Greece. This resource which is fished commercially (PT Tragakis, Halkidiki, Greece, pers. comm.) was almost certainly greater in the Bronze Age when fishing was far less intensive. Albacore feed on anchovies and pilchards and their arrival in the Aegean would coincide with the appearance of these smaller pelagic fish. Figure 15 confirms that an albacore population is present off western Crete (Gallant 1985 : 30). These fish would have been harvested by the Minoans and other Cycladic islanders, and this population is probably represented in the fish faunal remains recovered at settlements on Crete and at Saliagos.

FIGURE 16

Distribution and fishing areas for the Mediterranean bonito *Sarda sarda*  
(Laevastu and Rosa 1963, Fig. 7)



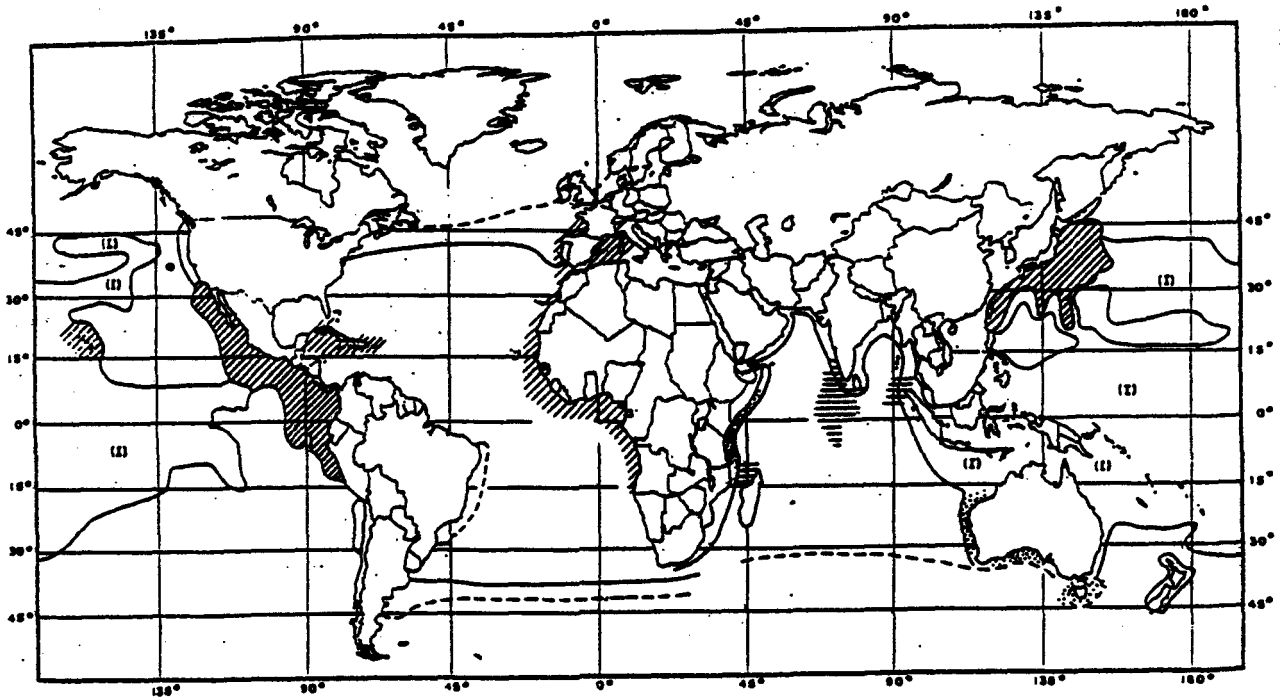
Distribution and fishing areas of bonitos (I) *Sarda lineolata* - *S. chilensis*  
(II) *S. velox* (III) *S. sarda* (IV) *S. orientalis* (V) *S. australis*

Figure 16 shows the extensive Mediterranean fishing grounds for the bonito *Sarda sarda*. This is the tuna species pictured in the Akrotiri fishermen fresco with a fisherman carrying his catch of three small bonito. Bonito are found in shoals and have a fairly wide water temperature tolerance that ranges from 14 to 27°C. The bonito *Sarda sarda* by virtue of its extensive distribution in the Mediterranean and its tendency to swim close to land would undoubtedly have been harvested by the Minoans and other Aegean islanders. Bonito spawn in the warmer tropical coastal waters and reportedly migrate to the west coast of Africa to breed. It is noteworthy that the distribution map shows a large resource of this tuna species along the bulge of Africa.

Figure 17 shows the distribution of skipjack tuna *Katsuwonus pelamis* or *Euthynnus pelamis*.

FIGURE 17

Distribution and fishing areas for skipjack *Euthynnus (Katsuwonus) pelamis*  
(Laevästu and Rosa 1963, Fig. 9)



Skipjack *Katsuwonus pelamis* represent one of the world's major tuna fisheries.

In Figure 17 skipjack are shown as commercially fished in the western Mediterranean but not in the Aegean. This is probably incorrect, since the existence of a skipjack resource is substantiated by the fact that skipjack and bonito together comprised 4,8% of the total 1958 Greek fishery catch (Gallant 1985 : 48).

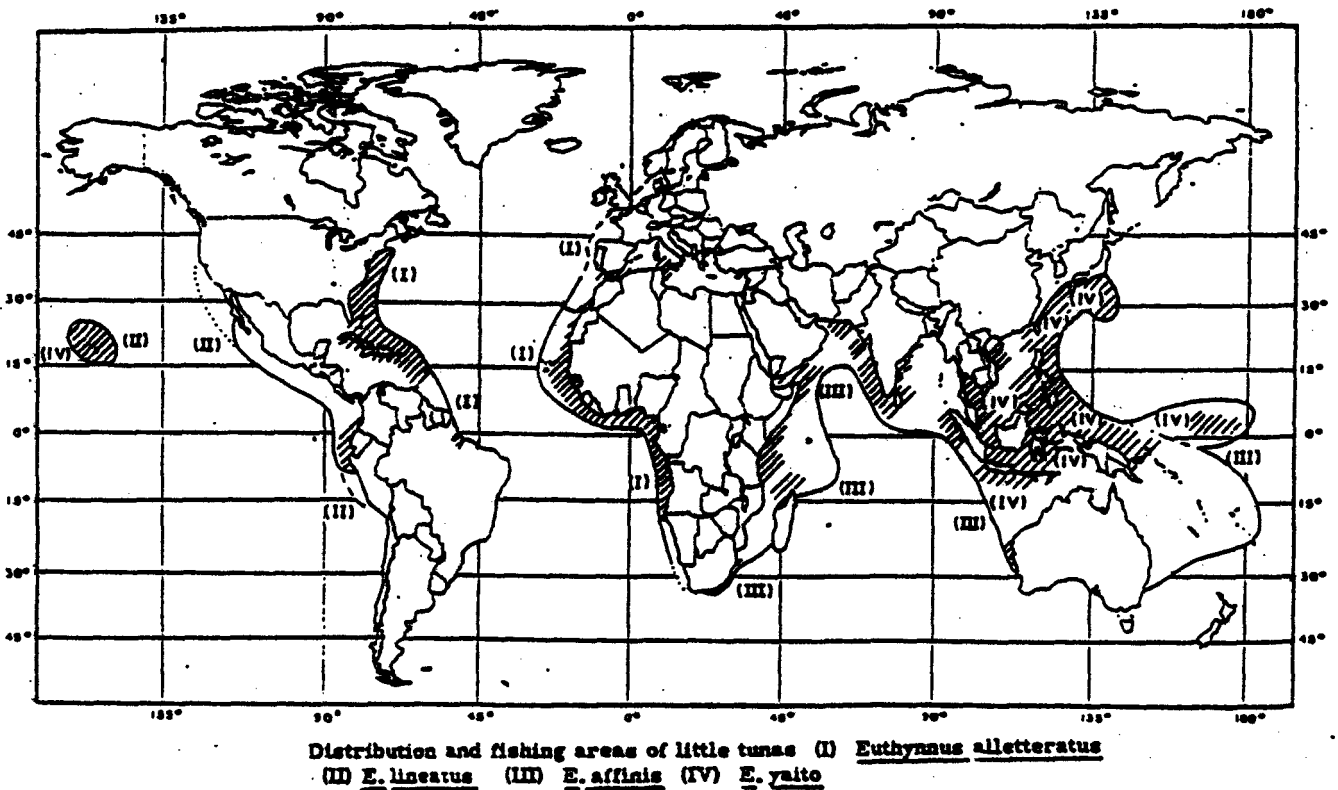
Like the bonito *Sarda sarda*, skipjack tolerate widely varying temperatures and are caught in waters ranging from 19 to 30°C. Feeding takes place at moderate depths and the fish spawn in coastal waters during summer. Because skipjack come inshore to spawn and swim at moderate depths (few penetrate below the warm water thermocline), they can be caught by a variety of methods. Most Aegean skipjack are caught on hook and line but long-lines as well as purse-seine nets are traditionally used. If nets are used catches of migrating skipjack can be

very large as the Japanese have demonstrated. The skipjack resource in the Aegean in the Bronze Age was an extremely useful one and would undoubtedly have contributed to Minoan and Cycladic diet and nutrition.

Figure 18 shows a small Mediterranean resource of the little tuna *Euthynnus alletteratus*.

FIGURE 18

Distribution and fishing areas of the little tuna *Euthynnus alletteratus*  
(Laevastu and Rosa 1963, Fig. 4)



Laevastu and Rosa (1963 : 13) and Gulland (1971 : 39) both state that small populations of the little tuna *Euthynnus alletteratus* are to be found to the east and west in the Mediterranean. At least one population would have been accessible to the Aegean Bronze Age fishermen. The little tuna is a wide-ranging oceanic gamefish that favours surface waters near continents and these two factors enable artisan fishermen to catch them. Little tuna are not harvested commercially in the West but in the Far East they constitute an important traditional protein source and are either smoked or sun-dried. It is therefore likely that these tuna, together with bonito and skipjack, were dried to constitute food when protein was scarce.

The final tuna species that is reported to be present in the Mediterranean is the frigate mackerel *Auxis thazard* (Faber 1883 : 198; Gallant 1985 : 59). Its presence is not recorded by the United Nations Food and Agriculture Organisation in Rome, indicating that they are of no commercial importance today. Frigate mackerel are small fish 4 to 6 kilograms in mass classified as tunas and which move inshore in the Mediterranean to spawn in June to July. Confined to small shoals they were suitable for harvesting by the Cycladic Bronze Age fishermen using fish traps, hook and line, nets and even lures carved from bone.

This review of the Mediterranean and Aegean tuna resource is based mainly on data provided by the International Tuna Commission and a publication of the World Scientific Meeting on the Biology of Tunas and Related Species (Laevastu and Rosa 1963). The information contained in these publications reinforces the Bronze Age archaeological evidence and Homeric and Classical sources for tuna fishing in the Aegean in the prehistoric period. It refutes opinion that the resource was a meagre one. The tuna distribution data presented here suggest that the primary species caught off Crete and in the Cyclades in the Bronze Age would have been albacore *Thunnus alalunga*, rather than the larger Atlantic bluefin tuna *Thunnus thynnus thynnus*, since an albacore population exists to the west of Crete (Laevastu and Rosa 1963 : 3, Fig. 5; Gallant 1985 : 30). Furthermore because these fish particularly favour inshore island waters, such as exist in the Aegean, they would have been easier to catch using Bronze Age fishing methods.

Table 19 contains a list of the smaller pelagic fish harvested in the Aegean, mainly fish of the *Clupidae* (herrings and sardines) and *Engraulidae* (anchovies) families.

TABLE 19

Smaller pelagic fish caught in the Aegean Bronze Age

Species	Habitat	References
Mediterranean pilchard <i>Sardina pilchardus</i>	Number of large populations, western and north-eastern Mediterranean, smaller populations in south-eastern region. Spawn in shallow water, biannual seasonal migrations. Annual catch (1971) 76 000 tons.	Gulland 1971:42 Gallant 1975:65 Faber 1883:31, 85, 100, 104, 147, 149, 156
Mediterranean sardine <i>Sardinella aurita</i>	More southerly distribution, caught commercially off north Africa. Annual catch with <i>S. maderensis</i> of 40 000 tons.	Oppian 1.244, 3.398 Gulland 1971:32, 42 Gallant 1985:59
Anchovy <i>Engraulis crasicholus</i>	Important pelagic shoal fish distributed throughout Mediterranean. Seasonal, eaten, salted or fresh. Mediterranean/Black Sea catch 226 600 tons in period 1963-1969.	Aristotle HA 569a-b 26-30 Aelian 2.2, 8, 19 Athenaeus VII.c.22 Xenocrates 7 Oppian 4.468-503 Gulland 1971:39 Faber 1883:45, 85, 100, 106, 114, 148, 161 Gallant 1985:50-51
Horse mackerel <i>Trachurus trachurus</i>	Shoals in open water, close inshore in summer, frequents off-shore sand banks. 4.6% of Mediterranean/Black Sea catch (15 000 tons 1963-1969).	Oppian 3.400 Gulland 1971:42 Faber 1883:32-33, 76, 106, 113, 148, 160 Gallant 1985:62 Mylona 1994
Sprat <i>Clupea sprattus</i>	Shoal species, northern Mediterranean. Annual catch exceeds 10 000 tons.	Athenaeus VII.e.28 Gulland 1971:39 Gallant 1985:70

Of the five smaller pelagic fish species caught in the Mediterranean and Aegean listed in Table 19 only bones of the horse mackerel *Trachurus trachurus* have been recovered from a Minoan Bronze Age settlement. Five otoliths, two positively and three tentatively identified as horse mackerel, were recovered at Palaikastro (Mylona 1994 : Appendix III). The absence of these smaller pelagic shoal fish is probably due to the small bone size and degradable nature.

On archaeological, literary and scientific evidence, it is not possible to quantify Bronze Age pelagic fish catches. Qualitatively the evidence suggests however that reasonable quantities of pelagic fish were caught. In reply to Gallant's argument on the inter-annual variability of the resource, it is pointed out that large capital-intensive international fisheries are centred on

predictable seasonal migratory patterns of pelagic fish. The *Scombridae* (tunas), *Clupidae* (herrings and sardines) and *Engraulidae* (anchovies) are all fished annually internationally on a sound economic basis. In all probability the Aegean resource of *Scombroid* fishes was greater in the Bronze Age than it is today, since evidence suggests that where the catches of bluefin tuna are poor, the cause in almost every instance is not a natural phenomenon, but simply gross over-fishing. Overfishing would not have occurred in the Bronze Age, thus leaving the bulk of the resource intact for small regular catches.

In contrast to the Bronze Age pelagic fishery evidence indicates that the Aegean littoral and demersal resource was characterised by a wider diversity of fish species. The tables that follow contain classifications of the littoral and demersal fish species caught off Crete, the Aegean islands and Greece in the Neolithic and Bronze Age periods. The first tables are compiled from the common names of fish recorded mainly in the writings of Classical authors. Subsequent tables cover the fish species recovered archaeologically from prehistoric settlement sites at Palaikastro in east Crete, Saliagos near Antiparos in the Cyclades and at Lerna in the Greek Argolid. The Bronze Age archaeological and Classical literary evidence on which the tables are based extend in time from the Aegean Middle Neolithic period (c. 4000 BC) to about 200 AD. It is generally accepted that an Aegean fishery model drawing on Classical sources is applicable to the Bronze Age because of the innate conservatism discussed earlier that characterises small-scale fishing (Gallant 1985 : 12; Mylona 1994 : 5,6). To place the identifications on a scientific footing the fish named by Classical authors were cross-checked where possible against twentieth century publications on prehistoric Aegean fishing (Ratcliffe 1921; Evans and Renfrew 1968; Gejvall 1969; Gallant 1985; Mylona 1994), as well as against publications dealing specifically with fish taxonomy and nomenclature (Smith 1949; Smith 1975; Van der Elst 1981; Smith and Heemstra 1991).

The identification of fish from Classical literary and Bronze Age archaeological sources is open to errors, as fish nomenclature even today is continually changing. The task is made more difficult as most countries have their own particular names for identical fish. The Aegean meagre (*Argyrosomus hololepidotus*) for example proved to be the South African kabeljou. Similarly the Aegean dentex a member of the Family *Sparidae* is related to the Cape red steenbras. The Aegean sargue proved to be the common Cape dassie and the Mediterranean dusky perch belongs to the same family as the Cape kingklip. Because of these taxonomic problems it proved

impossible in some instances in compiling the tables to positively identify fish described by the Classical writers in terms of modern nomenclature. Certain other fish could only be placed within their respective Families and not identified as to species. Taken as a whole however the classifications of Aegean fish that follow provide a reasonably sound comparative picture of the littoral and demersal resource in the Aegean in the period c. 4000 BC to about 200 AD.

TABLE 20

Littoral and demersal fish caught in the Aegean in the proto- and prehistoric periods

Species	Habitat and characteristics	References
<b>(a) Family Sparidae (Sea breams)</b>		
Annular Gilthead bream <i>Sparis annularis</i>	Inshore shoal fish, feeds on seaweed and small crustacea. Good eating. 0.68% of 1938 Greek catch.	Oppian 1.109 Smith 1991:580
Gilthead bream <i>Sparus auratus</i>	Rocky reefs, brackish water. Inshore spring and summer. Good eating. 0.73% of 1938 Greek catch.	Aristotle HA 598a 10; Oppian 3.188 Aelian 13.28; Plutarch SA 977f Smith 1991:580
Black bream <i>Spondyliosoma cantharus</i>	Inshore, rocky reefs and coasts, estuaries. Spawns April-May.	Oppian 3.338-70 Aristotle HA 598a 10 Smith 1991:581
Bogue <i>Boops boops</i>	Shoalfish, moves inshore in summer to spawn. Excellent eating when fresh.	Aristotle HA 610 b 4 Oppian 1.110 3.185; Smith 1991:581
Saupe <i>Sarpa sarpa</i>	Abundant in rocky coastal areas. Breeds in estuaries in winter. Tasty when fresh.	Oppian 1.125 Smith 1991:593
Braize <i>Diplodus vulgaris</i>	Rocky shores, estuaries, inshore fish. Good eating.	Aristotle 598 a 13; Oppian 1.140 3.183 Smith 1991:580
Sargue <i>Diplodus sargus</i>	Inshore, rocks and reefs. Good eating. Known as Cape 'dassie'.	Oppian 1.173 Smith 1991:586
Dentex <i>Dentex dentex</i>	Moves annually from deep to inshore waters. Excellent food fish that is preserved by smoking. 1.09% of 1938 Greek catch.	Aristotle HA 610 b 5 Oppian 3.610-9 Aelian 1.46 Smith 1991:580
Sea bream <i>Pagrus pagrus</i>	Annual migration inshore waters from deeper (20 metre) water. Good eating when fresh.	Oppian 4.385; Aelian 13.2 Plutarch SA 977c Gallant 1985:56
Spanish sea bream* <i>Papellus bogareveo</i>	Offshore, 200-500 metres, bottom feeder.	Pliny 32.31 Gallant 1985:70
Saddled bream* <i>Oblada melanoura</i>	Inshore shoal fish 2-3 metres bottom feeders. Good eating.	Oppian 3.443-481 Gallant 1985:66

\*Unlisted in 1991 Smith's Sea Fishes.

Table 20 contd**(b) Family Labridae (Wrasses)**

Brown wrasse <i>Labrus merula</i>	Coastal inshore shallow water fish, rocky coasts, bottom feeders.	Aristotle HA 567 b 18 607 b 19 Hippocrates DP 2.221; Smith 1991:683
Green wrasse <i>Labrus turdus</i>	Inshore, prefers rocky coasts, seaweed beds, bottom feeder. Good eating.	Aristotle HA 598 a 11 Oppian 1.126; Smith 1991:683
Rainbow wrasse <i>Halichoeres iridis</i>	Form small groups, winter in deep water and move inshore to rocky coasts. Largest exceeds one metre in length.	Aristotle HA 610 b 6; Plutarch SA 977 f Athenaeus <i>cited</i> Gallant, not verified; Oppian 1.124; Smith 1991:695
Peacock wrasse <i>Grenilabrus tinca</i>	Inshore species, rocky coasts, seaweed beds, bottom feeder, form small groups.	Plutarch SA 977 e; Aelian 1.14 Oppian 1.509/4.172-241 Gallant 1985:64

**(c) Families Muraenidae and Congridae (Eels)**

Conger eel <i>Conger conger</i>	Lives in rocky crevices along coast. Annual migrations from inshore to deep water. Excellent food fish; 0.15% of 1938 Greek catch.	Strabo 3.27; Galen 6.72.7 Smith 1991:161-162 Gallant 1985:55
Eel <i>Anguilla anguilla</i>	Prefers muddy bottoms at the outlet of rivers and lagoons. Migrates to sea to spawn. Excellent food fish.	Faber 1883:22, 38-9, 161 Smith 1949:387 Gallant 1985:57
Moray eel <i>Muraena helena</i>	Inhabits rocky coasts, found singly or in pairs. Edible but not particularly good eating.	Pliny 32.13 Oppian 1.142, 3,117, 189 Gallant 1985:63

**(d) Skate, Ray, Sole, Flounder and Stargazer****Families Rajidae (Skates) and Batoidea (Rays)**

Skate <i>Raja asterias</i>	Found on muddy or sandy bottoms, usually at 7-40 metres, bottom feeder.	Oppian 3.141; Gallant 1985:68 Smith 1991:118
Electric ray <i>Torpedo torpedo</i>	Found in water 2-40 metres, on sandy bottoms, solitary nocturnal feeder. Good eating.	Galen 40; Athenaeus VII.c.26 Smith 1991:108

**Family Soleidae (Soles)**

Sole <i>Solea vulgaris</i>	Inshore and shallows to 80 metres, solitary bottom feeders.	Oppian 1.105; Smith 1991: 868 Gulland 1971:42
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**Family Bothidae (Flounders)**

Flounder <i>Rhombus maximus</i>	Inshore, lives on sandy bottom, solitary feeder. Good eating. With sole and turbot 0.59% of 1963-69 Mediterranean/Black Sea catch.	Gulland 1971:42 Smith 1991:854
Flounder <i>Platichthys flesus</i>	Coastal, inshore, found in lagoons, estuaries, bottom feeder. Excellent eating.	Oppian 1.99 Smith 1991:854

**Family Uranoscopidae (Stargazers)**

Stargazer <i>Uranoscopus scaber</i>	Inshore, sandy or muddy bottom, solitary bottom feeder. Lie buried in mud awaiting prey.	Aelian 13.4 Oppian 2.199.244 Smith 1991:735
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**Table 20 contd****(e) Family Serranidae (Sea basses and Rock cods)**

Dusky perch (grouper) <i>Ephinephelus guaza</i>	Shallow coastal waters to moderate depths rarely exceeding 200 metres. Found in rocky bottoms and seaweed beds.	Aristotle HA 543 b 1, 591 a 11 Oppian 1.142 3.187 Smith 1991:515
Sea bass <i>Dicentrarchus labrax</i>	Shore to 100 metres. Summer migration into fresh water, solitary bottom feeder. With red fish comprise 16,9% of 1963-69 Mediterranean/Black Sea catch. Farmed commercially 1987 Cephalonia.	Plutarch SA 977 b, f Oppian 1.114 3.121 128-30 Gallant 1985:67 Fish Farmer, Sept 1987, 30-32

**(f) Family Centracanthidae (Picarels)**

Picarel <i>Maena smaris</i>	Migrates annually from deep to shallower inshore water in summer.	Geopon 20.35 Smith 1991:249-245
Blotched picarel <i>Maena maena</i>	Annual summer migration to shallower water. Together with picarel comprised 28,5% of 1938 Greek catch.	Aristotle HA 569 b 28 Athenaeus cited Gallant, not verified Pliny 31.83 Smith 1993:595

**(g) Class Cephalopoda (Octopus and Squid)**

Squid <i>Loligo vulgaris</i>	Both oceanic and inshore, caught at night using lights. Excellent eating as calamari.	Personal observation in eastern Crete
Cuttlefish <i>Sepiola rondeleti</i>	Open water	Rackham & Moody 196:196
Octopus <i>Octopus vulgaris</i>	Rock pools and shallows. Caught by spearing. Excellent eating.	Aristotle HA IV.8 Radcliffe 1921:178 Evans & Renfrew 1968:80, 137

**(h) Shad and Sprat**

Shad <i>Alosa fallax nilotica</i>	Small fish of the herring family. Shoals in deep water, rises to feed at night. 7,7% of the Mediterranean/Black Sea catch 1963-69.	Oppian 3.397 Gallant 1985:67
Sprat <i>Clupea sprattus</i>	Shoal fish, prey of other fish and birds, resemble pilchard, diurnal vertical movement.	Athenaeus VII.e.28 Gallant 1985:70

Table 20 contd

## (i) Miscellaneous other Families

**Family Lophidae (Angler fish)**

Angler fish <i>Lophius piscatorius</i>	Inshore, rocky to muddy bottom, coral reefs. Good food fish, sometimes referred to as 'monk fish'.	Oppian 2.86 Smith 1991:365
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**Family Squatinidae (Angel shark)**

Angel shark <i>Squatina squatina</i>	Usually depth of 60-400 metres. Caught inshore in surf.	Athenaeus VII.c.44 Smith 1991:107
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**Family Coryphaenidae (Dolphinfish, Dorado)**

Dolphinfish (dorado) <i>Coryphaena hippurus</i>	Oceanic species but drift into estuaries. Are occasionally caught off (Cape) beaches. Very partial to flying fish as food. Excellent eating.	Aristotle HA 543 a 24, 569 b 3 Oppian 1.184, 3.186, 4.404-36 Smith 1991:661
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**Family Mugilidae (Mulletts)**

Grey mullet <i>Mugil cephalus</i>	Temperate seas, estuaries and rivers great tolerance of fresh water, bottom feeder. 1.2% of Mediterranean/Black Sea catch 1963-69.	Aristotle HA 568 a 7, 541 a 22, 601 b 21, 621 b 9; Oppian 3.99-116, 482-528 Plutarch SA 977a Smith 1991:718
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**Family Mullidae (Surmulletts, goatfish)**

Red mullet <i>Mullus surmuletus</i>	Shallow water estuaries, bottom dwellers. 11.6% of 1938 Greek catch.	Aristotle HA 570 b 22, 598 a 10 Plutarch SA 977 f; Aelian 2.41 Oppian 3.432-442
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**Family Peristediidae (Armoured gurnards)**

Gurnard <i>Peristedion cataphractum</i>	Inhabit the lower shelf/upper slope regions. Small groups, coastal, occasionally enter brackish water. Edible but not particularly desirable.	Oppian 1.97 Athenaeus cited Gallant, not verified Smith 1991:489
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**Family Merlucciidae (Hakes)**

Hake <i>Merluccius merluccius</i>	Deepsea fish, 100-1000 metres. Feeds on mackerel, sardine. Good eating and important food fish. 5.5% of 1938 Greek catch; 1.3% of 1963-69. Mediterranean/Black Sea catch.	Oppian 1.151 Plutarch SA 977 f Smith 1991:324
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**Family Belonidae (Garfishes)**

Garpike <i>Belone belone</i>	Inshore coastal surface, shoal in summer and spring. Good eating, and make good bait.	Aristotle HA 610 b 6 Oppian 3.576 Smith 1949:129
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**Family Carangidae (Kingfishes)**

Horse mackerel <i>Trachurus trachurus</i> (Cape maasbanker)	Shoal fish, 10-100 metres, move inshore in summer, offshore sandbanks.	Oppian 3.400 Gallant 1985:62 Smith 1991:660
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**Family Scianidae (Meagre)**

Meagre <i>Argyrosomus hololepidotus</i> (Cape kabeljou)	Common down to 100 metres, frequently enters estuaries, takes almost any bait, also spinners. Good eating if free of parasites.	Aristotle HA 570 b 21, 607 a 24, 610 b 5; Oppian 1.123 3.169 Aelian 13.17 217
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Table 20 and the archaeological evidence that follows indicate that fish of the Family *Sparidae* (sea bream) were an important littoral species harvested in the Aegean in antiquity. The tables demonstrate that at least eleven different species of bream were caught. Faunal remains from Building I Palaikastro, Table 21 (Middle Minoan - Late Minoan) (Mylona 1994 : Appendix III) and Saliagos (Middle Neolithic) (Evans and Renfrew 1968 : 118), Table 22, confirm the harvesting of *Sparidae*.

Table 21 contains an analysis of the fish remains from Palaikastro.

TABLE 21  
Fish faunal remains from Palaikastro, eastern Crete\*

Family	Species	Otoliths	Bones
<i>Dasyatidae</i>	<i>Dasyatis</i> sp.	-	1
<i>Serranidae</i>	<i>Serranus</i> /hepatus	22	-
	? <i>Serranus</i> sp.	8	-
	<i>Anthias</i> / <i>anthias</i> / <i>Calanthias ruber</i>	16	-
	<i>Serranidae</i> indet	33	8
<i>Apogonidae</i>	<i>Apogon imperbis</i>	1	-
<i>Carangidae</i>	<i>Trachurus trachurus</i>	2	-
	<i>Trachurus</i> ? <i>trachurus</i>	3	-
	<i>Carangidae</i> indet	10	-
<i>Pomacentridae</i>	<i>Chromis chromis</i>	26	-
<i>Sciaenidae</i>	<i>Sciaena</i> sp.	-	1
<i>Mullidae</i>	? <i>Mullus</i> sp.	-	1
<i>Sparidae</i>	<i>Diplodus sargus</i>	1	-
	<i>Diplodus</i> sp.	2	-
	<i>Lithognathus mormyrus</i>	1	1
	<i>Spondylisoma cantharus</i>	4	-
	<i>Pagellus acarne</i>	4	-
	<i>Pagellus</i> ? <i>erythrinus</i>	-	1
	<i>Pagrus pagrus</i>	-	1
	<i>Sparus aurata</i>	-	1
	<i>Boops boops</i>	7	-
	<i>Boops</i> ? <i>boops</i>	10	-
	<i>Sparidae</i> indet	26	24
<i>Centracanthidae</i>	<i>Maena smaris</i>	1	-
	<i>Maena vulgaris</i>	6	-
	<i>Maena</i> sp.	10	-
	<i>Centracanthidae</i> indet	32	10
<i>Blennidae</i>	<i>Blennius</i> sp.	-	8
<i>Atherinidae</i>	<i>Atherina</i> sp.	3	-
<i>Sparidae</i> / <i>Labridae</i>	<i>Sparidae</i> indet/ <i>Labridae</i> indet	-	8
Unidentified		19	46
<b>TOTAL</b>		<b>247</b>	<b>108</b>

\*Building I, Palaikastro.

(Mylona 1994 : 15; MacGillivray *et al* 1992 : 121-52)

At Palaikastro recovery of bones and otoliths shows that bream comprised some 26% of the fish faunal remains and was the second most common family (81%), represented by 53 otoliths and 28 bones. Although the majority of remains came from small species, for example *Spondyliosoma cantharus*, *Pagellus acarne* and *Boops boops* there is some evidence for several medium to large fish, for example *Pagrus pagrus*, *Lithognathus mormyrus* and the Gilthead bream *Sparus aurata*. The otolith morphology of some *Sparidae* for example *Boops boops* suggests that the Palaikastro fishermen were catching young as well as mature specimens (Mylona 1994 : 7-9).

Table 22 contains the identification and analysis of the fish faunal remains from Saliagos.

TABLE 22

## Fish faunal remains from Saliagos near Antiparos

(a) The number of bones of each family of fishes found in each phase of the settlement

*Phase	Scombridae	Sparidae	Serranidae	Carangidae	Shark/Ray	Total identified	Total found
1, Pit A	1930	8	-	2	2	1942	2118
1, elsewhere	38	3	4	1	-	46	60
2	75	-	3	2	1	81	89
1 or 2	131	2	1	4	-	138	140
3	222	4	1	7	-	234	241
1,2 or 3	212	3	2	25	-	242	272
<b>TOTALS</b>	<b>2608</b>	<b>20</b>	<b>11</b>	<b>41</b>	<b>3</b>	<b>2683</b>	<b>2920</b>

(b) The numbers of different bones represented for each family of fishes

	Scombridae	Sparidae	Serranidae	Carangidae	Shark/Ray	Total
Dentaries	-	-	2	1	-	3
Premaxillae	1	18	-	-	-	19
Teeth	-	2	-	-	-	2
Quadrates	-	-	-	6	-	6
Vertebrae	2532	-	9	34	3	2578
Hypurals	11	-	-	-	-	11
Finrays, etc	64	-	-	-	-	64
<b>TOTALS</b>	<b>2608</b>	<b>20</b>	<b>11</b>	<b>41</b>	<b>3</b>	<b>2683</b>

\*Chronologically Middle to Late Neolithic period

(Evans and Renfrew 1968 : 89, 120)

At Saliagos Sparid bones comprised 15% of the littoral fish caught. The remains of *Sparidae* are found in all phases of the settlement excepting the second and are represented by the premaxillae and molarform teeth of *Sparus aurata*. Jane Renfrew estimates that these Gilthead bream were up to 45 cm in length (Evans & Renfrew 1968:118).

Table 23 contains an analysis of the fish remains from Lerna on the Greek mainland.

TABLE 23  
Fish faunal remains from Lerna, Greece

Settlement level	Fish species	Family	Description of find
I and II	<i>Argyrosomus hololepidotus</i> Cape kabeljou	<i>Sciaenidae</i>	Premaxillary bone from large specimen c. 1,3 metres in length
II	<i>Thynnus thynnus</i> Bluefin tuna	<i>Scombridae</i>	Two vertebrae of one individual tuna
	<i>Argyrosomus hololepidotus</i> Cape kabeljou	<i>Sciaenidae</i>	Fragment of basioccipal and parasphenoideum bone, possibly kabeljou
II and III	<i>Thynnus thynnus</i> Bluefin tuna	<i>Scombridae</i>	One small and one caudal vertebrae
III	<i>Carcharhinus glaucus</i> Great blue shark	<i>Carcharhinidae</i>	Four vertebral centres, fragment of vertebra
IV	<i>Galeorhinus galeus</i> Gray shark	<i>Carcharhinidae</i>	Small vertebrae centre
V	<i>Sparus aurata</i> Gilthead bream	<i>Sparidae</i>	Large left dentale

Note: Level I Early Neolithic  
II Middle Neolithic  
III Early Helladic II  
IV Early Helladic III  
V Middle Helladic  
(Gejvall 1969 : 49-50)

The fish faunal remains from Lerna in the Argolid also reveal the presence of *Sparus aurata* in the form of a large left dentale (Gejvall 1969 : 50). Gilthead bream is a desirable food fish much prized by the Greeks in the 19th century. The desirability and fecundity of the *Sparidae* species, first recorded by Aristotle (HA 598a 10), has led to the artificial cultivation of Gilthead bream on the Greek island of Cephalonia, where since 1987 some 80 tonnes of fish are harvested annually (Fish Farmer 1987). Thus proto-historic records, archaeological evidence and

modern fishery science all contribute evidence to substantiate an Aegean fishery that extends well back into the Neolithic period.

Other littoral and demersal fish species common to both literary sources and the archaeological faunal records were fish of the families *Serranidae* (sea basses and rock cod) and the *Carangidae* (kingfishes). At Palaikastro the analysis shows that *Serranidae* are particularly well represented, 84% of the bones and otoliths recovered being from this family of fishes. Most of the remains are of small species, for example *Serranus hepatus*, *Serranus* sp., and of medium size fish such as *Athias anthias/Calanthias ruber*. Larger fish of the *Serranidae* family could be represented amongst the unidentifiable featureless bones (Mylona 1994 : 4). At Saliagos the *Serranidae* are represented by vertebrae and a dentary plate, the size of which suggests the largest of the Mediterranean Serranids *Epinephalus gigas*. These rock cod are not found in the early deposit in Pit A but are found elsewhere in all phases albeit in small numbers. The presence of rock cod in the deposits suggests that the Aegean fishermen c. 4000 BC developed the necessary skill for catching them. Their faunal remains indicate substantial fish of about a metre in length (Evans and Renfrew 1968 :118). Rock cod are today of considerable commercial importance because of their food value, particularly so in local subsistence fisheries similar to those that existed in the Aegean Later Neolithic and Bronze Ages.

Demersal fish of the *Carangidae* species are referred to by Oppian (3.400) and their remains were recovered on Crete and in the Cyclades. Fish of the *Carangidae* family include horse mackerel *Trachurus trachurus* and amberjack *Seriola dumerilii* as well as the Cape yellowtail *Seriola lalandi*. At Palaikastro 15 otoliths from *Carangidae* species were recovered from Building I, these otoliths comprising 4% of the fish remains. The otoliths were identified as those of small to medium size horse mackerel (Mylona 1994 : Table I). At Saliagos the bones of *Carangidae* species were quantitatively second only to those of *Scombroid* (tuna) remains. Vertebrae, quadrates and a dentary represent a species of *Carangidae* larger than the horse mackerel found at Palaikastro, the remains occurring in all phases of the Middle Neolithic settlement. The morphology and size of the bones indicate that the fish caught were either *Seriola dumerilii* (amberjack) or *Lichia glauca*. Jane Renfrew suggests that the fish caught at Saliagos probably exceeded a metre in length (Evans and Renfrew 1968 : 120). This is credible since the South African angling record for amberjack is 33,1 kg (Van der Elst 1981 : 131).

Both *Trachurus trachurus* and *Seriola* sp. are of considerable importance from a nutritional standpoint. Today they are caught in the Mediterranean in quantity either by trawling or purse-seining (Gulland 1971 : 39). Of relevance to the prehistoric Aegean is that both horse mackerel and amberjack are still caught by artisan fishermen using beach seines, a method identical to that described by the ancient writers (Plutarch SA 977f, Oppian 3.124, 4.490-503; Aelian 1.141). In the case of a migratory seasonal inshore 'run' by either of these species large quantities can be landed on a beach within a few hours.

Apart from *Sparidae*, *Serranidae* and *Carangidae* described by the classical authors and confirmed by fish faunal remains from Saliagos (Table 22) and Palaikastro (Table 21), other Aegean littoral and demersal fish are recorded in Tables 20-23. Aristotle (HA 570b 21, 607a 24, 610b 5), Aelian (13.17) and Oppian (1.123, 3.169, 217) refer to an Aegean fish of the Family *Sciaenidae* called the meagre, *Argyrosomus regius* (Gallant 1985 : 63). This fish is probably either the same species or related to *Argyrosomus hololepidotus*, which was recovered at Lerna I and II (Early and Middle Neolithic) (Gejvall 1969 : 49). The premaxillary bone recovered was from a large specimen about 1,3 metres in length. *Argyrosomus hololepidotus* is an oceanic fish that also frequents shallow coastal waters, particularly along the sandy edges of reefs and estuaries where the water is often turbid. It is therefore possible that *Argyrosomus* species were caught by Aegean Bronze Age fishermen by spearing in the shallow estuarine water during the spawning season. At Palaikastro (Middle/Late Minoan) the family *Sciaenidae* is represented by the otolith of a large fish, the exact species of which unfortunately could not be identified (Mylona 1994 : Appendix III).

Other edible fish common to the Classical authors and the faunal remains from Saliagos and Lerna are those of the cartilaginous group, i.e. the sharks and rays. Both these species frequent shallow sandy inshore areas but are also found in deeper offshore water. Lerna in Greece provides evidence for the catching of sharks, shark remains being recovered from both Early Helladic II and Early Helladic III levels. Four vertebral centres of one individual fish and a further fragment of vertebra of another both identified as the blue shark *Carcharhinus glaucus*, were recovered from the Early Helladic II layer. A further vertebral centre of another shark identified as the grey shark *Galeorhinus galeus* was recovered from the Helladic III level (Gejvall 1969 : 50). Sharks range in size from the giant basking shark at some 15 metres to the smallest of the *Squaliolus* sharks that may not exceed 15 cm. The yield of edible meat from shark varies

between 20 and 60 per cent of body mass and differs from species to species. Nutritionally shark is very high in vitamin A. The liver of certain sharks contains some 100 times the vitamin A level of cod liver oil (Ronsivalli 1978 : 11).

Sharks also have unique non-food properties that would have been useful in the Aegean Bronze Age. Because of the hardness of the scales and their close proximity the abrasive properties of shark skin were used in antiquity for sanding wood and polishing marble (Ronsivalli 1978 : 11). Shark skin may also have been used for leather since it is easily tanned using vegetable agents such as tree bark.

The ray *Torpedo torpedo* is mentioned by Aristotle (HA 620b 19), Athenaeus (VII.c.26) and Galen (40) (Gallant 1985 : 58) and the shark *Squatina squatina* is referred to by Athenaeus (356d, 357c). Gallant (1985 : 51) describes this as an angelfish but it is probably an angelshark (Smith 1949 : 61). At Saliagos vertebrae of these cartilaginous fish were recovered from Pit A and a stratum of Phase 2 of the settlement. The largest of the vertebrae suggests a fish of some 1,5 metres in length. The remains were simply identified as shark or ray with the probability being that they were shark (Evans and Renfrew 1968 : 119). From Palaikastro (Middle/Late Minoan) comes evidence for the catching of rays, the family *Dasyatidae* being represented by the sting from a young ray (Mylona 1994 : Appendix III). Rays occur along the sandy surf zone, in muddy estuaries and river mouths and on offshore banks to depths of 50 metres. Rays take a variety of baits and are sometimes taken in nets as by-catch.

The catching of inshore fish of the *Centracanthidae* family is recorded by Aristotle (569b 28) and Pliny (31.83). The recovery of remains of these fish on Crete at Palaikastro confirms their harvesting in the Middle Minoan/Late Minoan period (Mylona 1994 : 4). Building I Palaikastro yielded remains of the picarels *Maena smaris* and *M. vulgaris*, these *Centracanthidae* comprising 59% of the fish identified at Palaikastro with 49 otoliths and 10 bones. Picarel (*Maena smaris* and *M. maena*) comprised 28% of the Aegean fish catch in 1938 (Gallant 1985 : 65), this figure taken together with that for 59% of the Middle/Late Bronze Age catch at Palaikastro confirming the importance of these fish in the Aegean fishery. Picarel, a food fish common in antiquity, can be preserved by salting. Picarel are also used to form the basis of a traditional fermented fish sauce. Fermented fish sauces are commonly used by peasant communities to add flavour to bland dishes that are based on a high cereal content.

Aristotle (HA 570b 22, 298a 10), Plutarch (SA 977f), Aelian (2.41), Athenaeus (III.c.87) and Oppian (3.432-442) all mention the littoral red mullet *Mullus surmuletus*, a fish of the *Mullidae* family. These fish known variously as red mullet, surmullet, goat fish or salmonette and make excellent eating. Mullet are found on sandy or muddy bottoms at depths of less than 15 metres the usual method of catching being netting. The mullet resource in the Aegean is limited but is a constant source of food. In 1938 mullet comprised 11,6% of the Greek fishery catch (Gallant 1985 : 66). At Palaikastro in eastern Crete mullet comprised 0,28% of the total fish remains for the Middle/Late Minoan period (Mylona 1994 : 14). Mullet thus formed a small though possibly significant component of the Bronze Age Cretan catch.

Good Mediterranean catches of mullet are also attested to by their popularity in the Roman period. Mullet, in particular the larger specimens that exceeded one kilogram in weight, fetched very high prices in Rome. Juvenal's scathing comments on Crispinus who paid some 6000 sesterces for a 3 kilogram mullet runs:

"What! You Crispinus, brought to Rome erewhile  
Lapt in the rushes of your ancient Nile,  
Buy scales at such a price! You might, I guess,  
Have bought the fisherman himself for less;  
Bought, in some countries, manors at this rate,  
And, in Apulia, an immense estate."

Sat. IV 23ff (Gifford's Translation)

The excessive price paid for large mullet in Rome is put into better perspective when the cost is compared with an artisan's annual earnings. If 1000 sesterces is taken as an artisan's annual wage, the cost of the fish was equivalent to six year's wages, a ridiculous price for a fish.

Octopus and squid remain popular Greek seafoods today, at Siteia the boats going out nightly to catch squid. Aristotle (HA IV.8) describes the catching of squid in antiquity. At Saliagos the identification of cuttlefish remains in Middle Neolithic levels suggests these also formed part of the diet (Evans and Renfrew 1968 : 137; Rackham and Moody 1996 : 196).

Comparison of the archaeological, Classical and scientific evidence for Aegean fishing suggests that the range of pelagic, demersal and littoral fish caught in the Bronze Age did not differ greatly from that recorded in fishery surveys conducted within the past twenty-five years (refer Table 7). Analysis of fish identified as caught by the Bronze Age Cretans and Cycladic

islanders shows a good variety of species. The evidence presently available is however insufficient to highlight any one particular fish as being of paramount interest to the Aegean population. The evidence available rather suggests a multi-species fishery that made optimum use of regional fishery resources. At Palaikastro on Crete emphasis was placed on the smaller inshore fish, whereas at Saliagos in the Cyclades seasonal migratory tuna was the optimum resource. The hypothesis for a multi-species Aegean fishery in the Bronze Age is supported by the Homeric and Classical texts that describe the catching of fish for consumption, these ranging in size from the small but highly prized red mullet in Roman times, to large bluefin tuna, as evidenced by the possible identification of a tuna vertebra from Knossos (Panagiotaki 1993 : 54,55, Fig. C).

The identification, classification and analysis of fish caught at settlements such as Lerna, Saliagos, Palaikastro and elsewhere provides regional data on Aegean fishing from the Middle Neolithic to Late Minoan IIIB. Taken together in temporal sequence these fishing records extend for almost three thousand years. Despite uniformity of basic fishing procedures, the analyses reveal that different patterns of fishing occurred. These different patterns of fishing were brought about primarily by the distribution and nature of the regional fish stocks. In addition to revealing the diversity of the Aegean marine resource, the analyses indicate the different contributions to nutrition that the fish catches made, particularly in terms of the available levels of essential fatty acids obtainable from the various fish species.

The faunal lists for Lerna for example show that this Neolithic/Bronze Age settlement on the Bay of Argos differed considerably from the two island settlements in that here fishing made a relatively minor contribution to the provision of animal protein for the community. The alternative sources of animal protein recorded included domestic dog and wolf, wild boar and domestic pig, sheep and goat, wild ox and domestic cattle, ass and horse, vole, hedgehog, red fox, brown bear, badger, otter, beech marten, weasel, lynx, hare, red deer and roe deer and birds, amphibians and reptiles (Gejvall 1969 : 14-50).

A total of 2587 bone fragments was recovered at Lerna dating from the Early Neolithic (Lerna I) to the Late Helladic (Lerna VI). Fish bones comprise less than 1% of the faunal remains recovered. Analysis of the animal bones shows that in the early years of the settlement protein consisted mainly of the flesh of wild animals such as ox, boar and deer supplemented by

birds and fish. By the Middle Neolithic evidence for the domestication of pig, cattle and sheep intrudes.

Small but consistent quantities of fish bones were recovered at Lerna with the exception of Lerna VII (Late Helladic III). The low proportion of fish material in the faunal remains at Lerna was at first due to the abundance of wild game in the region in the Neolithic, which in turn was replaced by domestication of sheep and cattle. The contribution of fishing to the community's diet was therefore minimal although the range of fish caught included Gilthead bream *Sparus auratus*, shark *Carcharhinus glaucus*, bluefin tuna *Thunnus thynnus thynnus* and croaker *Argyrosomus hololepidotus* (*ibid* : 49,50), some of these fish species being common to catches made at Palaikastro and Saliagos.

The faunal evidence from Lerna thus supports a role and contribution for fishing that is not too dissimilar to the model of the farmer-fisherman proposed by Gallant (1985 : 38), fishing making a small but important contribution to the diet and economy of the settlement. The major factor in minimising the role of fishing was the siting of Lerna on the Greek mainland in an area of good natural resources, followed by the domestication of sheep and cattle.

Table 24 shows the total number of bone fragments for mammals, fish and shellfish recovered from Middle Neolithic at Saliagos near Antiparos. The table includes calculations of the minimum number of animals and the expected meat weight (Evans and Renfrew 1968 : 79).

TABLE 24

Weight of meat represented in Cliff 17, Pit A, and in Square N3 by species

Species	Cliff 17, Pit A				Square N3	
	No. of fragments	Min. number of animals	Meat wt per animal	Total meat wt (kg)	Min. number of animals	Total meat wt (kg)
Sheep/goat	2595	17	29 kg	490	22	640
Bovine	32	1	210 kg	210	6	1260
Pig	96	4	45 kg	180	10	450
Tunny	1930	48	135 kg	6500	7	940
Other fish	358	-	-	-	-	-
<i>Patella</i>	1900	1900	3,5 g	6,5	1970	6,90
<i>Monodonta</i>	340	340	1,0 g	0,35	650	0,65
<i>Murex</i>	140	140	5,0 g	0,70	216	1,80
<i>Cerastoderma</i>	90	45	1,0 g	0,05	53	0,05

Notes: (i) Minimum numbers calculated for livestock on the number of humerus found, for tunny on the number of vertebrae, at 39 vertebrae per fish.

(ii) Meat weight for livestock is taken as half modern liveweight.

(iii) Meat weight of tunny is taken as 135 kg, a rough average for fish of length 0,6 to 1,8 metres.

(iv) There were insufficient cephalopod remains preserved to allow of their incorporation in the table.

Source: Evans and Renfrew 1968 : 79, Table 23

The table indicates that *caprini* (sheep/goats) were also important to the economy and protein diet of the Aegean island. They represent 83,5% of the total mammalian remains and examination of the bones suggests that over 90 per cent of the *caprini* were sheep. Unlike Lerna on the Greek mainland there is no evidence of hunting and wild game formed no part of the Saliagos diet.

Table 24 emphasises that fishing made a major contribution to the economy and diet of the settlement. Fish bones represent 45,65% of the total faunal remains in Cliff 17, Pit A. Jane Renfrew has pointed out that nearly all the fish bones recovered at Saliagos were very large (Evans and Renfrew 1968 : 78). This preponderance of large bones could in part be due to the more fragile and rapid deterioration of smaller bones as well as to practical difficulties in recovering them. If this assumption is correct the percentage of fish could have been even greater than 45,65%. The faunal analysis indicates that the range of fish caught was varied and included *Scombridae*, *Sparidae*, *Serranidae* and *Carangidae* as well as sharks or rays and cephalopods.

With regard to the contribution of fishing to the island's economy and diet it is significant that ninety-seven per cent of all fish bones recovered were those of tuna often of a large size. Reference to Table 24 shows that Pit A and Square N3 together yielded the remains of 55 tuna if we take 39 vertebrae per tuna. At an average of 135 kg per fish the total weight of tuna exceeds 7 tons. A catch this size requires fishing skill and compares favourably with the 1969 total catch of Mediterranean bluefin tuna which was only 10 tons (Gulland 1971 : 42). The obvious question of how long it took to catch more than 7 tons of tuna cannot be answered. The quantity caught does suggest however that the seasonal migration routes were well known and that harvesting took place on a regular basis. It has been pointed out earlier than the geomorphology of Saliagos probably aided tuna catching. Evidence indicates that the sea level was lower at the time of settlement (Evans and Renfrew 1968 : 98).

The faunal analysis from Palaikastro provides a third alternative view of the contribution of fishing to the economy and diet of an Aegean settlement. At Palaikastro the contribution of fishing was less than that of Saliagos but well exceeded that of the dietary contribution at Lerna. At Palaikastro all the remains analysed come from Building I one of the occupation units at the east fringe of the Bronze Age town. The function of Building I is uncertain but the building phases which date the fish remains run from a Pre-Building I phase (Middle Minoan II-III) to a partial reconstruction in Late Minoan II-IIIa. The fish remains, both bones and otoliths, were recovered from a building the size, plan and construction of which suggests a domestic dwelling of a wealthy person. Some finds suggest the building also housed cult activities.

The fish remains in Building I represent 11 Families amongst which are 15 species and 8 genera. The analysis suggests that catches consisted mainly of smaller fish typical of an inshore environment. Fish that live on rocky bottoms include *Serranidae*, *Pomadasiidae*, *Apogonidae* and some *Sparidae*. Other fish recovered in Building I include *Bleinnidae* and some *Sparidae* that frequent muddy estuarine water. Pelagic and deepwater fish found at Palaikastro, *Carangidae* and *Trachurus trachurus*, were probably caught on their annual inshore migration to spawn.

The contribution of fish to the protein diet of a Middle Minoan/Late Minoan household is difficult to assess in the absence of any data on mammalian remains. The excavator suggests however that the contribution of fish to the diet, based on faunal remains, was certainly less than that of sheep and cattle, but that the difference was probably not as wide as would be envisaged

(Mylona 1994 : 9). The faunal evidence indicates that the fish caught at Palaikastro was not a major food resource but rather represented a stable supply of specific nutrients. Fish also provided variety in a diet that was probably dull and characterised by quantities of cereal and sheep/goat meat.

The faunal evidence from Lerna, Saliagos and Palaikastro demonstrates three differing roles for the fishermen of the communities. Whereas at Lerna the task of feeding the settlement had shifted in the Neolithic period from the hunter to the farmer leaving the fisherman as only a minor contributor, on Saliagos and at Palaikastro on Crete the fishermen remained important providers of protein-rich food. These differences in the role and contribution of the fishermen were brought out by a wide range of factors that included the availability of other sources of animal protein, the insular nature and richness of the regional fish resource and the level of fishing skills.

Further evidence for a multi-species fishery and the dietary contribution of fish in the Aegean comes from the island of Melos. The evidence from Melos is more circumstantial however since few Bronze Age fish remains have been recovered. The contribution of fish is clearly evident from the illustration of Melian fishermen on a vase found at Phylakopi (Ratcliffe 1921 : 62). The vase depicts four fishermen each carrying two fish that closely resemble the dolphin fish *Coryphaena hippurus*. Bintliff (1977 : 540) suggests that fishing had a central role in the economy of the island which fortuitously is surrounded by good fishing grounds, fishing being the only remaining maritime activity on the island which today provides Piraeus with iced fish. Renfrew recovered the bones of small fish at Phylakopi but no large tuna bones. This suggests that Melos unlike Saliagos is off the regular tuna migration route. As at Palaikastro on Crete alternative smaller species of fish made up the bulk of the catches. This assumption is confirmed by a list of fish caught off Melos compiled from earlier records (Wagstaff, Augustson and Gamble 1982 : 172-180). The fish listed include anchovy, red mullet, bream, brown comber, rays, octopus and squid.

Melos advantageously has marine salt pans that would have provided salt for preserving fish, salted sun-dried fish providing excellent protein in times of food scarcity. The island was self-sufficient for food up to the 18th century the inhabitants living on a diet consisting mainly of cereals, fish and olive oil supplemented by mutton or goat. Despite the lack of faunal remains

from Bronze Age fishing the evidence suggests that Melian fishing followed the pattern of a multi-species fishery, as seen at Palaikastro and to a lesser extent at Saliagos.

At Gournia in eastern Crete bronze fish hooks of various sizes, a lead sinker and stone net weights described earlier provide adequate evidence for fishing. Despite the absence of Bronze Age fish remains the hooks indicate that fish of different species and size were caught, again pointing to a multi-species fishery that contributed food to the community.

### PLATE 3

Middle-Late Minoan settlement at Gournia showing proximity to Bay of Mirabello



### 6.3 Determination of the fatty acid composition of some fish and cephalopods that formed part of the Aegean and Minoan Bronze Age diet

The intention in this section is to briefly review current recommendations by international health authorities for the intake of polyunsaturated fatty acids that are essential for good health. The analyses of fish oils for fatty acid composition and contents that follow demonstrate that quantifiable levels of these essential dietary fatty acids are present in certain common fish that formed part of the Cretan diet in the Bronze Age.

Earlier discussion suggested that the traditional diet of Crete had changed little between the Bronze Age and the period immediately after World War II. Evidence revealed that as recently as 1948 the Cretan diet contained a high cereal content, the wheat and barley consumed on the island still being produced using primitive agricultural methods (Allbaugh 1953 : 269). This high cereal diet was augmented by fish, meat, vegetables, pulses, fruit and nuts. The comprehensive dietary survey undertaken by Allbaugh showed that about 18% of protein in the islanders' traditional diet was derived from fish or meat. Allbaugh estimated that the *per capita* consumption of fish per week on Crete was approximately 170 grams, the fish eaten being mainly common Aegean species such as smelt (small agile fish of the Family *Parapercidae*), mullet, sea bream and octopus (*ibid* : 110). In 1988 fish consumption on Crete exceeded 200 g/week (Kafatos *et al* 1991 : 591-598, *cited* Tornaritis *et al* 1993 : 135).

Considerable research has been carried out in the past decade to show that the *n*-3 polyunsaturated fatty acids present in fish oils are beneficial to human health. Currently emphasis is placed on determining the metabolic role of two of these important fatty acids, notably eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The principal *n*-3 and *n*-6 polyunsaturated fatty acids are summarised in Table 25. (It should be noted that the designations *n*- and *omega*- are interchanged in the literature but present convention is to use *n*-.)

TABLE 25

Principal *n*-3 and *n*-6 polyunsaturated fatty acids

Alpha-linolenic acid	C18:3	<i>n</i> -3
Eicosapentaenoic acid	C20:5	<i>n</i> -3
Docosahexaenoic acid	C22:6	<i>n</i> -3
Linoleic acid	C18:2	<i>n</i> -6
Arachidonic acid	C20:4	<i>n</i> -6

Source: Barlow and Pike 1991 : 18

Recent clinical and animal studies on the social, nutritional and biochemical involvement of docosahexaenoic (DHA) and eicosapentaenoic acid (EPA) demonstrate that the *n*-3 long-chain polyunsaturated fatty acids are essential for the normal development of brain and nervous tissue. Furthermore these fatty acids produce a variety of beneficial effects in the treatment of blood vessel and inflammatory diseases (Barlow and Pike 1991 : 18-26; Renaud *et al* 1995 : 1360S-1367S). At the present time knowledge of the dietary requirements for these essential fatty acids is not generally reflected in international nutritional recommendations. In the 9th edition of the United States Recommended Daily Allowances (1980) for example it is stated that the metabolic function of linolenic acid C18:3 is unclear and no figures for daily dietary requirements are given. In the following 10th edition published in 1989 the dietary essentiality of linolenic acid is recognised, but no recommendations for *n*-3 fatty acid intake are given. In support of the recognition however proposals by Neuringer *et al* (1988 : 517-541) are included, which recommend that the intake of *n*-3 polyunsaturated fatty acids should be 10-25% of that of the *n*-6 fatty acid linoleic C18:2. This fatty acid (linoleic) is fairly important (*ca.* 10%) in olive oil, but alpha-linolenic is not.

The committee responsible for the preparation of the 2nd edition of the Nordic Nutrition Recommendations (1989) was more positive. The Nordic Council of Ministers accepted that sufficient information was available to estimate minimal adequate dietary intakes of both *n*-3 and *n*-6 fatty acids. They therefore recommended that the essential fatty acids (i.e. the sum of both *n*-3 and *n*-6 fatty acids) should provide at least 3% of the energy intake for normal healthy individuals. It is noteworthy that they recommended that the diet of pregnant women should contribute 4,5% of these fatty acids and for lactating mothers the requirement should be at least 6%. The committee further recommended that the *n*-3 polyunsaturated fatty acids should provide at least 0,5, 0,8 and 1% of energy requirements for these respective population groups.

An optimum dietary ratio of 5:1 for *n*-6 to *n*-3 unsaturated fatty acids was recommended by the Nordic Council of Ministers. This recommendation was based on the proportions of these essential fatty acids found in normal foetal and neonatal lipids and human milk.

To obtain some idea of what constitutes an adequate daily dietary intake of these two essential fatty acids it is necessary to refer to American information since no equivalent data is available for Crete. This is unfortunate since the United States diet is highly Westernised and rich

in saturated fats. From a nutritional standpoint it contrasts poorly with the traditional Cretan diet, as evidence presented earlier showed the Cretan diet to be low in saturated fat and high in cereals. Furthermore the Cretan diet contains both fish and olives that would favour the intake of polyunsaturated fatty acids. It is estimated that the average American consumes about 17 grams of *n*-6 and *n*-3 fatty acids per day (Barlow and Pike 1991 : 18-22). Based on the recommended 5:1 ratio referred to earlier this would require about 3 grams of *n*-3 polyunsaturated fatty acids per day. In practice the average American consumes about 1,7 grams of *n*-3 with some 90% of this being linolenic acid C18:3. There is thus a deficiency of at least 1 gram of *n*-3 polyunsaturated fatty acid *per capita* per day in the American diet. Barlow and Pike suggest that the principal deficiency would be in the important long-chain DHA and EPA fatty acids (*ibid* : 19), both of which are present in and obtainable from many common sub-tropical Atlantic and Mediterranean fish as analyses that follow demonstrate.

The chemical analyses for the fatty acid composition of fish, undertaken by the South African Fishing Industry Research Institute, were carried out on 17 different species identified from Aegean archaeological records, further confirmed by Classical literary sources. Also included for comparative purposes is a yellowfin tuna *Thunnus albacares* a warmer water Atlantic species. The fish analysed were obtained from different sources through the South African Fishing Industry Research Institute, and the Institute's method for analysis of fish oil fatty acid composition is included in the Appendix. Some of the fish for example the Mediterranean sardine *Sardinella aurita* were caught by Russian freezer trawlers fishing off North Africa. Other fish such as the dolphin fish *Coryphaena hippurus* were obtained from freezer trawlers operating from Cape Town. Different species of tuna for example *Thunnus alalunga*, *Thunnus thynnus thynnus* and *Katsuwonus pelamis* were obtained from commercial catches taken off the Cape west coast.

With regard to using fish caught in different regions for this research it must be pointed out that for commercial purposes it is generally accepted that differences found in the fatty acid composition of similar fish are more likely to be caused by biochemical factors than by geographic considerations. Ackman (pers. comm.) states that the fatty acids of the fish body oil may change depending on local food sources.

For comparison, analyses from Crete (Tornaritis *et al* 1993 : 135-139) and Greece (Karakoltsidis *et al* 1995 : 258-273) are included in later discussion.

The following tables show the fatty acid composition per cent for fish flesh of the *Trachurus* species Family *Carangidae* caught off the Chilean and South African coasts and anchovy of the Family *Engraulidae* caught off South Africa, Chile, California and Peru. *Trachurus trachurus* was identified amongst the faunal remains from the Middle-Late Minoan settlement at Palaikastro on Crete (Mylona 1994 : Appendix III), and catches of anchovy in the Aegean are recorded in both the Classical and later literature reviewed (Gulland 1971 : 39; Gallant 1985 : 50).

TABLE 26

Fatty acid composition (% of fish oil) of *Trachurus* species  
Family *Carangidae* caught off Chile and South Africa

	Fatty acid composition, %			
	Chile		South Africa	
	North	South	Nov. '85	March '86
14:0	7,2	7,2	8,7	8,6
15:0	0,8	0,8	0,3	0,3
16:0	19,4	19,6	14,0	17,6
16:1	7,8	8,5	6,9	9,0
16:3	-	-	1,5	1,3
16:4	-	-	1,9	1,4
17:0	1,0	1,1	0,2	-
18:0	3,4	3,9	2,7	3,9
18:1	12,2	15,2	6,4	11,9
18:2	1,2	1,1	1,1	1,2
18:3	0,6	0,6	-	-
18:4	2,0	1,9	1,8	1,3
20:0	-	-	0,4	0,3
20:1	2,0	1,8	9,1	5,8
20:3	-	-	0,3	0,3
20:4	0,6	0,7	1,1	1,0
<b>20:5n-3 EPA</b>	<b>16,4</b>	<b>12,6</b>	<b>10,9</b>	<b>12,6</b>
21:5	-	-	0,4	0,3
22:0	-	-	0,2	-
22:1	1,0	1,1	18,1	11,2
22:5	2,2	1,8	1,8	2,2
<b>22:6n-3 DHA</b>	<b>12,8</b>	<b>14,3</b>	<b>5,9</b>	<b>6,5</b>
24:1	-	-	1,0	0,5
Other	9,4	7,8	5,3	2,8

Source: Young 1988, Appendix 2

Note: Chilean sampling differentiated geographically, South African seasonally.

TABLE 27

Fatty acid composition (% of fish oil) of anchovy of the Family *Engraulidae* caught off South Africa, Chile, California and Peru

	Fatty acid composition, %				
	South Africa	Chile		Baja California	Peru
		North	South		
14:0	6,9	11,2	10,3	8,3	7,5
15:0	-	1,3	0,4	1,0	0,6
16:0	20,3	20,4	16,7	19,5	17,5
16:1	9,4	7,9	11,3	9,1	9,0
17:0	-	2,0	0,5	1,1	0,6
18:0	3,7	6,8	3,1	3,3	4,0
18:1	13,7 <sup>a</sup>	12,2	9,0	16,9 <sup>a</sup>	14,0 <sup>a</sup>
18:2	1,0	3,3	1,3	0,9	1,9
18:3	-	0,8	0,3	0,6	1,3
20:1	3,5 <sup>b</sup>	2,0 <sup>b</sup>	7,8 <sup>b</sup>	4,5 <sup>b</sup>	4,8 <sup>b</sup>
20:4	0,8	0,3	0,3	0,9	0,8
<b>20:5<math>\omega</math>-3 EPA</b>	<b>19,6</b>	<b>10,1</b>	<b>18,5</b>	<b>18,2</b>	<b>17,0</b>
22:1	2,6	2,0	3,8	1,6	1,2
22:5	1,3	1,0	1,8	-	1,6
<b>22:6<math>\omega</math>-3 DHA</b>	<b>9,3</b>	<b>9,2</b>	<b>4,3</b>	<b>10,9</b>	<b>8,8</b>
Other	7,9	9,5	10,6	3,2	9,4
Iodine value	-	-	163	185	181

Source: Young 1988, Appendix 1

a = Combined 18:1 and 16:4 acids

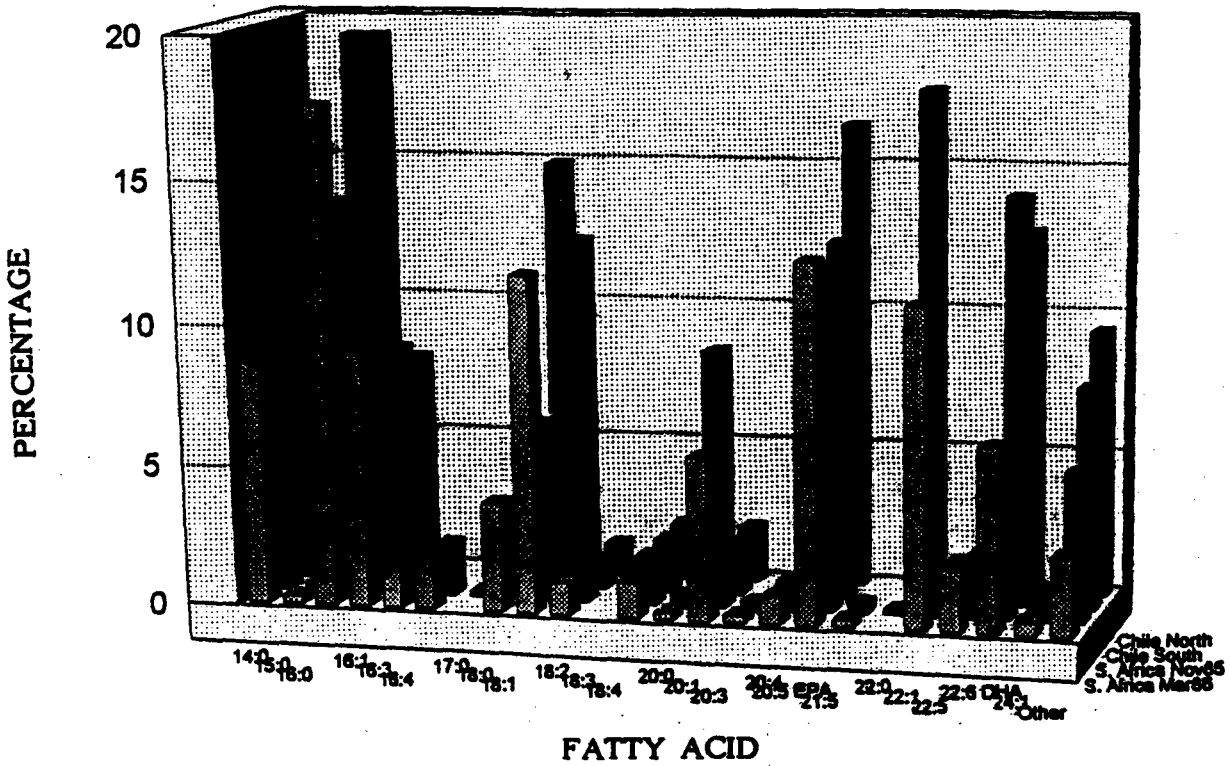
b = Combined 20:1 and 18:4 acids

The above analyses include fish from fishing grounds extending from the Cape west coast to Chile, Peru and California. Notwithstanding some anomalies in the figures, the analyses generally support the assumption that fish of the same species caught thousands of sea miles apart have reasonably comparable fatty acid contents. A noticeable anomaly in Table 26 is the DHA content of the South African *Trachurus* species that is some 50% lower than the Chilean sample. Differences such as these could be due to variations in feeding patterns. Ackman (pers. comm.) suggests that the reason for the difference in DHA content between the *Trachurus* species may be ecological. He notes that the North Atlantic herring eating copepods have a high content of 22:1 totalling 20-35% of fatty acid. Menhaden within a few hundred miles of the herring eat no copepods and have almost no 22:1 in their body oil.

Figures 19 and 20 show computer analyses of the data contained in Tables 26 and 27. Whilst the anchovy show good comparison of the DHA and EPA contents in fish from South Africa, Chile, California and Peru, the graphical representation of *Trachurus* would probably be improved if a greater number of fish were included in the analyses.

FIGURE 19

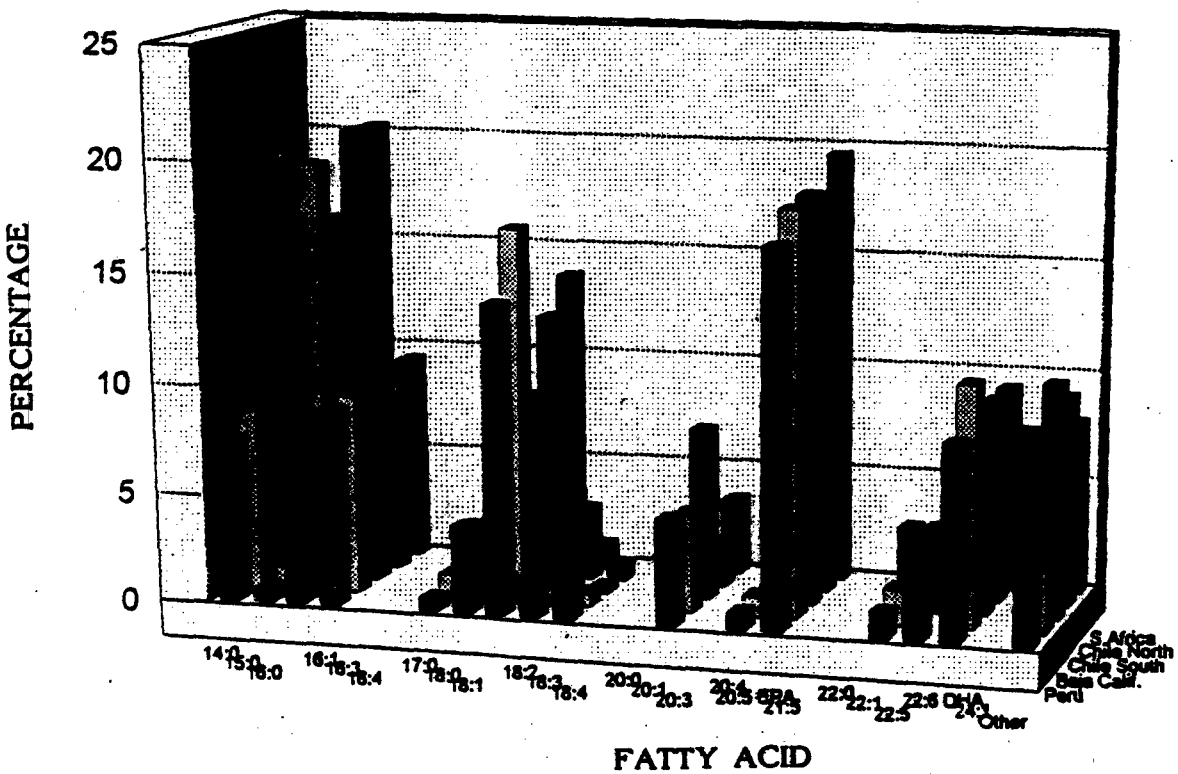
Comparison of fatty acid composition of Family CARANGIDAE (Trachurus sp)



Source: Young 1988, Appendix 2. (Table 27)

FIGURE 20

Comparison of fatty acid composition of Family ENGRAULIDAE



Source: Young 1988, Appendix 1. (Table 28)

The tables that follow contain fatty acids analyses of fish species similar to those identified from Minoan, Cycladic and Helladic archaeological remains. The variations in fat content (where available) should be noted.

TABLE 28

Fatty acid composition (% total fat) of albacore (*Thunnus alalunga*), skipjack (*Katsuwonus pelamis*), bluefin (*Thunnus thynnus thynnus*) and yellowfin (*Thunnus albacares*)

Fatty acid	Albacore longfin tuna <i>Thunnus alalunga</i>	Skipjack tuna <i>Katsuwonus pelamis</i>	Bluefin tuna <i>Thunnus thynnus thynnus</i>	Yellowfin tuna* <i>Thunnus albacares</i>
C12:0	-	0,1	-	-
C14:0	0,4	1,1	4,2	0,6
C15:0	-	0,4	1,0	-
C16:0	21,6	19,4	25,4	18,0
C17:0	0,3	0,6	1,1	-
C18:0	7,0	8,5	9,0	7,5
C19:0	-	0,3	-	-
C20:0	-	-	-	-
C22:0	-	-	-	-
C24:0	-	-	-	-
<b>Total saturated</b>	<b>29,3</b>	<b>30,4</b>	<b>40,7</b>	<b>26,1</b>
C16:1	0,9	1,4	4,5	1,3
C18:1 $\omega$ -9	9,7	-	29,1	8,9
C18:1 $\omega$ -7	1,8	-	3,1	1,4
C20:1	2,2	-	4,5	1,1
C22:1 $\omega$ -11	0,9	-	-	-
C22:1 $\omega$ -9	-	-	-	-
C22:1 $\omega$ -7	-	-	-	-
C24:1	0,3	1,8	-	-
<b>Total monoenes</b>	<b>15,8</b>	<b>3,2</b>	<b>41,2</b>	<b>12,7</b>
C16:4	-	-	-	-
C16:3	-	-	-	-
C18:4 $\omega$ -3	-	11,7	-	-
C18:3 $\omega$ -6	-	-	-	-
C18:2	0,9	1,8	-	0,3
C20:4 $\omega$ -6	3,8	3,1	-	4,3
<b>C20:5<math>\omega</math>-3 EPA</b>	<b>4,9</b>	<b>5,6</b>	<b>3,2</b>	<b>4,0</b>
C20:4 $\omega$ -3	-	-	1,2	-
C20:3 $\omega$ -3	-	0,7	-	-
C21:5	-	-	-	-
<b>C22:6<math>\omega</math>-3 DHA</b>	<b>36,9</b>	<b>36,5</b>	<b>12,3</b>	<b>38,7</b>
C22:5 $\omega$ -3	1,3	0,6	1,3	0,9
<b>Total polyunsaturated</b>	<b>47,8</b>	<b>60,0</b>	<b>18,0</b>	<b>48,2</b>
Unidentified	7,1	6,51	0,1	13,1
Protein (%)	25,5	26,7		
Fat (%)	0,7	6,51		

\*Not identified in the Aegean but included for comparative purposes.

Source: Fishing Industry Research Institute, Cape Town

TABLE 29

Fatty acid composition (% total fat) of Mediterranean sardine (*Sardinella aurita*), mackerel (*Scomber scomber*), horse mackerel (*Trachurus trachurus*) and striped mullet (*Mullus surmuletus*)

Fatty acid	Mediterranean sardine <i>Sardinella aurita</i>	Mackerel <i>Scomber scomber</i>	Horse Mackerel <i>Trachurus trachurus</i>	Striped mullet <i>Mullus surmuletus</i>
C12:0	0,2	-	-	-
C14:0	7,3	6,2	8,7	3,5
C15:0	0,5	1,1	0,3	0,4
C16:0	20,2	24,8	14,0	19,7
C17:0	0,7	1,0	0,2	0,5
C18:0	4,4	5,2	2,7	4,8
C19:0	-	0,2	-	-
C20:0	0,6	0,3	0,4	0,3
C22:0	0,2	-	0,2	-
C24:0	0,2	-	-	-
<b>Total saturated</b>	<b>34,3</b>	<b>38,8</b>	<b>26,5</b>	<b>28,9</b>
C16:1	8,4	6,5	6,9	7,6
C18:1 <i>n</i> -9	6,2	15,0	6,4	21,6
C18:1 <i>n</i> -7	3,5	3,5	-	3,5
C20:1	0,7	3,1	9,1	3,2
C22:1 <i>n</i> -11	0,3	2,0	18,1	3,2
C22:1 <i>n</i> -9	0,1	0,8	-	0,5
C22:1 <i>n</i> -7	0,2	-	-	-
C24:1	0,9	0,4	1,0	0,7
<b>Total monoenes</b>	<b>20,2</b>	<b>31,3</b>	<b>41,5</b>	<b>40,3</b>
C16:4	1,6	-	1,9	-
C16:3	1,3	-	1,5	0,6
C18:4 <i>n</i> -3	3,6	0,9	1,8	0,4
C18:3 <i>n</i> -6	-	-	-	-
C18:2	1,7	1,0	1,1	1,0
C20:4 <i>n</i> -6	1,5	1,7	1,1	1,7
<b>C20:5<i>n</i>-3 EPA</b>	<b>15,7</b>	<b>7,9</b>	<b>10,9</b>	<b>6,3</b>
C20:4 <i>n</i> -3	0,8	0,5	-	0,6
C20:3 <i>n</i> -3	0,4	0,5	0,3	0,1
C21:5	0,7	-	0,4	0,2
<b>C22:6<i>n</i>-3 DHA</b>	<b>12,7</b>	<b>13,3</b>	<b>5,9</b>	<b>16,1</b>
C22:5 <i>n</i> -3	1,9	1,8	1,8	2,5
<b>Total polyunsaturated</b>	<b>41,9</b>	<b>27,2</b>	<b>26,7</b>	<b>29,5</b>
<b>Unidentified</b>	<b>3,6</b>	<b>2,7</b>	<b>5,3</b>	<b>1,3</b>
<b>Protein (%)</b>		<b>19,5</b>		<b>20,7</b>
<b>Fat (%)</b>		<b>2,7</b>		<b>2,9</b>

Source: Fishing Industry Research Institute, Cape Town

TABLE 30

Fatty acid composition (% total fat) of red sea bream (*Sparus aurata*), hake (Family *Merlucciidae*), dolphinfish (*Coryphaena hippurus*) and gurnard (Family *Trigla*)

Fatty acid	Red sea bream <i>Sparus aurata</i>	Hake Family <i>Merlucciidae</i>	Dolphinfish <i>Coryphaena hippurus</i>	Gurnard Family <i>Trigla</i>
C12:0	-	-	-	-
C14:0	3,1	1,3	0,6	3,2
C15:0	-	0,3	-	0,4
C16:0	19,5	18,6	17,1	19,9
C17:0	-	0,6	0,6	0,4
C18:0	8,6	4,6	7,4	4,9
C19:0	-	0,2	-	-
C20:0	-	0,2	-	-
C22:0	1,7	-	-	-
C24:0	-	-	-	-
<b>Total saturated</b>	<b>32,9</b>	<b>25,8</b>	<b>25,7</b>	<b>28,8</b>
C16:1	5,2	3,0	1,6	9,8
C18:1 <i>n</i> -9	13,5	7,2	11,3	22,7
C18:1 <i>n</i> -7	-	2,6	2,0	5,7
C20:1	2,1	1,7	-	-
C22:1 <i>n</i> -11	-	0,9	-	2,8
C22:1 <i>n</i> -9	-	-	-	-
C22:1 <i>n</i> -7	-	-	-	-
C24:1	-	0,4	-	0,4
<b>Total monoenes</b>	<b>20,8</b>	<b>15,8</b>	<b>14,7</b>	<b>41,4</b>
C16:4	1,5	-	-	-
C16:3	1,5	-	-	-
C18:4 <i>n</i> -3	-	0,6	0,7	1,2
C18:3 <i>n</i> -6	-	-	-	-
C18:2	1,8	0,8	-	-
C20:4 <i>n</i> -6	5,3	2,0	5,7	1,4
<b>C20:5<i>n</i>-3 EPA</b>	<b>7,3</b>	<b>9,5</b>	<b>4,7</b>	<b>5,9</b>
C20:4 <i>n</i> -3	-	0,4	-	0,4
C20:3 <i>n</i> -3	-	0,2	-	-
C21:5	-	-	-	-
<b>C22:6<i>n</i>-3 DHA</b>	<b>20,3</b>	<b>38,2</b>	<b>38,3</b>	<b>13,8</b>
C22:5 <i>n</i> -3	3,7	1,7	2,4	0,4
<b>Total polyunsaturated</b>	<b>41,4</b>	<b>53,4</b>	<b>51,8</b>	<b>23,1</b>
<b>Unidentified</b>	<b>5,9</b>	<b>5,0</b>	<b>7,8</b>	<b>6,7</b>
<b>Protein (%)</b>		<b>17,0</b>	<b>22,2</b>	
<b>Fat (%)</b>		<b>0,5</b>	<b>0,5</b>	

Source: Fishing Industry Research Institute, Cape Town

TABLE 32

Fatty acid composition (% total fat) of sole (*Solea vulgaris*),  
squid (*Loligo vulgaris*) and octopus (*Octopus vulgaris*)

Fatty acid	Sole <i>Solea vulgaris</i>	Squid <i>Loligo vulgaris</i>	Octopus <i>Octopus vulgaris</i>
C12:0	-	-	-
C14:0	4,2	2,5	2,7
C15:0	0,4	0,4	-
C16:0	16,2	24,6	23,8
C17:0	0,7	0,5	1,0
C18:0	6,9	2,8	10,0
C19:0	0,2	-	-
C20:0	0,4	0,1	-
C22:0	0,2	-	-
C24:0	-	-	-
<b>Total saturated</b>	<b>29,2</b>	<b>30,9</b>	<b>38,4</b>
C16:1	6,2	1,5	0,7
C18:1 <i>n</i> -9	10,7	4,1	7,2
C18:1 <i>n</i> -7	4,0	1,4	-
C20:1	3,0	4,6	3,8
C22:1 <i>n</i> -11	1,3	0,4	1,7
C22:1 <i>n</i> -9	-	0,2	-
C22:1 <i>n</i> -7	0,3	-	-
C24:1	0,2	0,3	-
<b>Total monoenes</b>	<b>25,7</b>	<b>12,5</b>	<b>13,4</b>
C16:4	-	0,1	-
C16:3	-	0,1	-
C18:4 <i>n</i> -3	0,1	0,9	-
C18:3 <i>n</i> -6	-	-	-
C18:2	1,4	0,7	-
C20:4 <i>n</i> -6	1,7	1,3	-
<b>C20:5<i>n</i>-3 EPA</b>	<b>7,3</b>	<b>14,3</b>	<b>16,1</b>
C20:4 <i>n</i> -3	-	0,2	6,3
C20:3 <i>n</i> -3	3,1	0,1	-
C21:5	0,2	-	-
<b>C22:6<i>n</i>-3 DHA</b>	<b>14,4</b>	<b>31,6</b>	<b>20,6</b>
C22:5 <i>n</i> -3	8,7	0,4	1,8
<b>Total polyunsaturated</b>	<b>36,9</b>	<b>49,7</b>	<b>44,8</b>
<b>Unidentified</b>	<b>8,2</b>	<b>6,51</b>	<b>3,4</b>
Protein (%)	17,4		
Fat (%)	1,9		

Source: Fishing Industry Research Institute, Cape Town

The eighteen fish analysed and recorded in Tables 28-32 include pelagic, demersal and littoral species. It is noteworthy that of all the fish analysed for fatty acid composition only two had lipids with docosahexaenoic acid (DHA) contents below 12%. These are *Trachurus trachurus* (5,9%) and the small littoral white bream *Diplodus sargus* (9,0%). The analyses of the tuna are particularly interesting with two of the three species identified as caught in the Aegean Bronze Age having DHA contents exceeding 36%. The yellowfin tuna (*Thunnus albacares*) a warmer water species included in Table 29 for comparative purposes has fat with a DHA content of 38,7% contrasting with albacore (*Thunnus alalunga*) and skipjack (*Katsuwonus pelamis*) yielding 36,9% and 36,5% respectively. All three contents can be considered high. The analysis of the bluefin tuna (*Thunnus thynnus thynnus*) present in the Cycladic and Minoan archaeological records is disappointingly low at 12,3% for the DHA and 3,2% for EPA. In all probability the fish was a poor specimen caught when food was seasonally short. Sampling could not be repeated as commercial fishing for bluefin tuna is prohibited due to an estimated 60% reduction in the Atlantic resource.

It is generally accepted as a rough guide to fish fatty acid composition content that the more heavily muscled fish such as tuna tend to be higher in DHA than EPA content. Conversely the smaller more oily pelagic fish for example pilchard and the mackerel *Trachurus trachurus* tend to have raised EPA levels concomitant with lower DHA contents. The four species of tuna analysed for fatty acid composition viz. *Thunnus thynnus thynnus*, *Thunnus alalunga*, *Thunnus albacares* and *Katsuwonus pelamis* all follow this trend. The Mediterranean bonito *Sarda sarda* which is classified as a tuna and is represented in the Aegean Bronze Age archaeological record is unfortunately not included in the fatty acid composition analyses. This is because the skipjack tuna *Katsuwonus pelamis* and the bonito are so similar in shape and configuration that they are not differentiated in commercial catches. However it is highly likely that the bonito *Sarda sarda* has satisfactory levels of DHA and EPA, bearing in mind the relatively uniform fatty acid composition profile of three of the four species of tuna analysed.

The demersal fish analysed for fatty acid composition viz. sea bream Family *Sparidae*, angelfish *Squatina squatina*, dolphinfish *Coryphaena hippurus* and the hake Family *Merlucciidae* all have lipids with good levels of DHA. The range of DHA levels extends from 20,3% for sea bream to a high of 38,3% for dolphinfish. EPA levels are correspondingly lower at 4,7% for the dolphinfish to 9,5% for hake.

Mediterranean mullet, *Mullus surmuletus*, represented in the Bronze Age faunal remains at Palaikastro and a popular food fish in Roman times, has fat containing a highly satisfactory DHA level of 16,1% and a lower EPA of 6,3%.

The analysis for fatty acid composition of the fat of the small inshore white bream *Diplodus sargus* is noteworthy, yielding a DHA of 9,0% and an EPA of 5,6%. Both these figures are relatively low when contrasted with the essential fatty acid contents of the tuna and larger demersal fish. These fatty acid levels could reflect a diet that is affected by the rocky wave-swept nature of the white bream's habitat.

Two traditional Greek marine foods squid *Loligo vulgaris* and octopus *Octopus vulgaris* are included in the fatty acid composition analyses. Both are represented in the Bronze Age archaeological and Classical records and both cephalopods have particularly good levels of DHA and EPA, the total lipids of squid and octopus having 31,6 and 20,6% of DHA and 14,3 and 16,1% of EPA respectively.

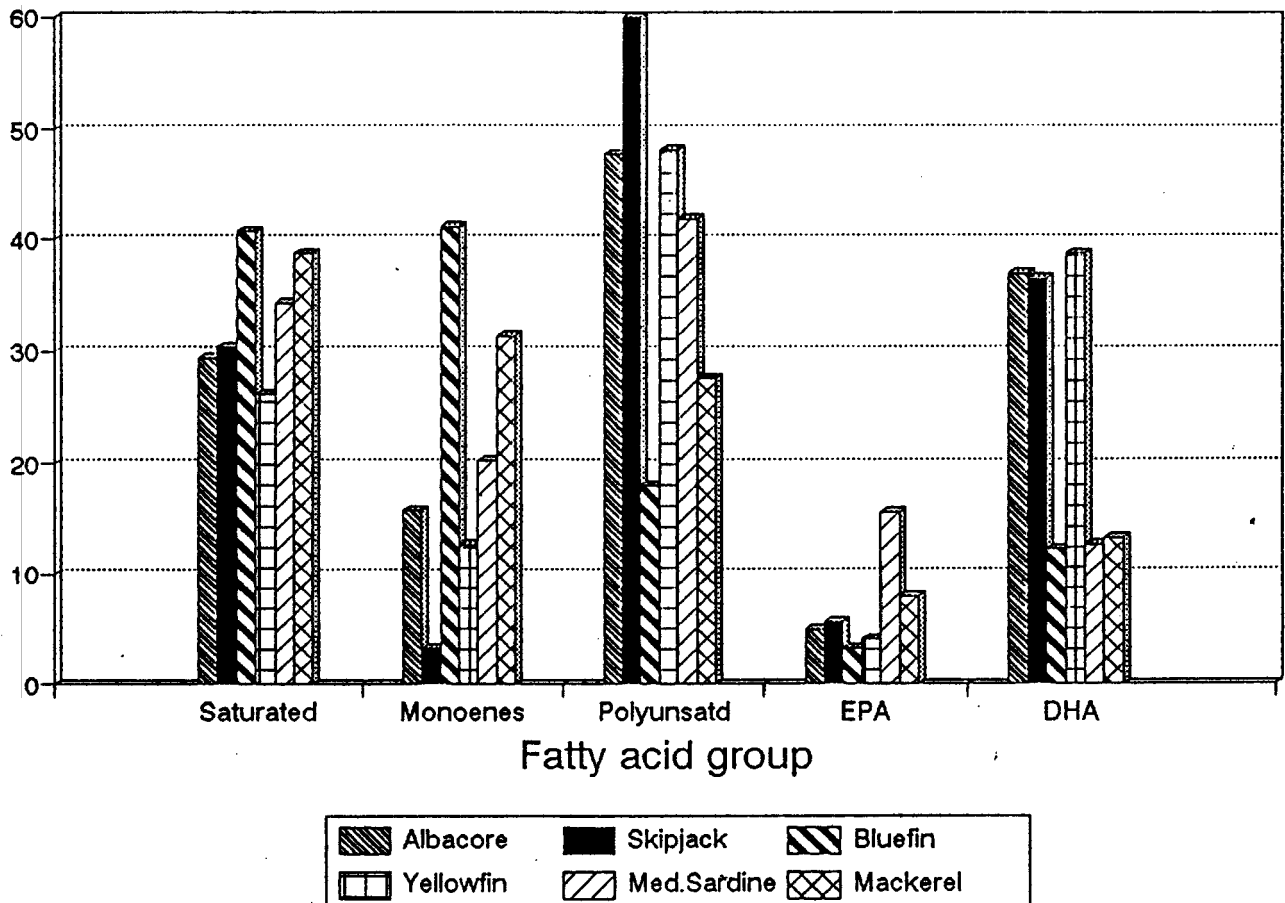
The Mediterranean sardine *Sardinella aurita* catches of which averaged 125 000 tons annually between 1963 and 1969 (Gulland 1971 : 42, Table C.41) gave an oil with an EPA content of 15,7% and DHA of 12,7%, which follows the trend mentioned earlier for oily fish to have raised EPA levels. The pattern is followed similarly by the mackerel *Trachurus trachurus* represented in Bronze Age strata at Palaikastro with an oil of EPA content of 10,9% and a lower DHA of 5,9%. The tendency is reversed for the other Mediterranean mackerel *Scomber scomber* which has an oil with an EPA of only 7,9% and a higher DHA level of 13,3%.

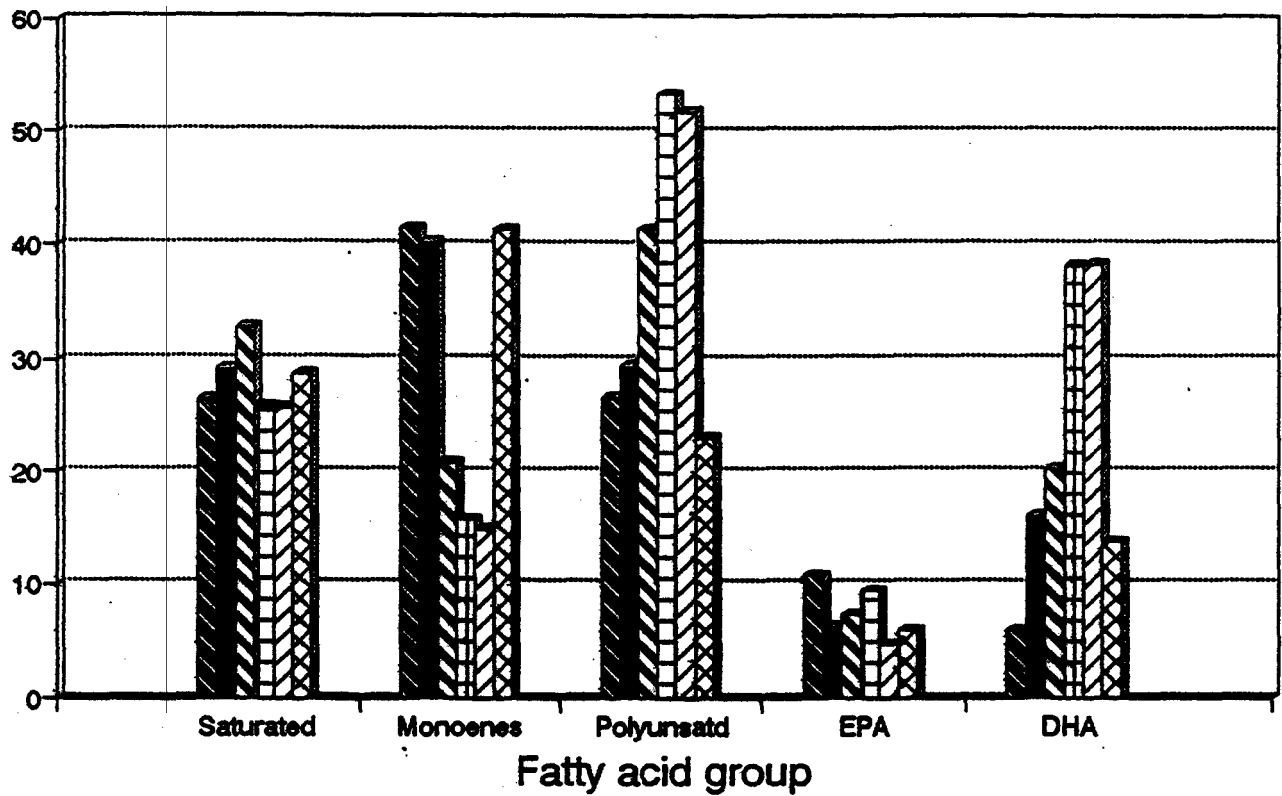
Of the three remaining fish analysed the lipids of the kob ("croaker") *Argyrosomus hololepidotus* have a satisfactory DHA content of 16,9% and a lower EPA of 6,4%. Faunal remains of this fish recovered at Lerna in the Bronze Age levels were from a large specimen estimated to be 1,3 metres in length. The gurnard analysed Family *Trigla* follows a similar trend with lipids with a DHA of 13,8% and a lower EPA content of 5,9%. The last fish represented in the analyses is the sole *Solea vulgaris*. This fish has lipids with a DHA of 14,4% and an EPA of 7,3% which is slightly higher than that of *Argyrosomus hololepidotus* (6,4%) and the gurnard (5,9%). All three fish represent Aegean foods that have good levels of protein (the protein

content of *Solea vulgaris* was 17,4%) and which contain satisfactory levels of two important *n*-3 fatty acids.

The fatty acid composition data contained in Tables 29-33 were analysed using a computer and the following graphs obtained. Figures 21, 22 and 23 illustrate the percentage fatty acid composition of the 18 fish. Figures 24 and 25 indicate the EPA and DHA contents of the fish fat. Figures 26 and 25 show the EPA and DHA contents calculated on the fish flesh.

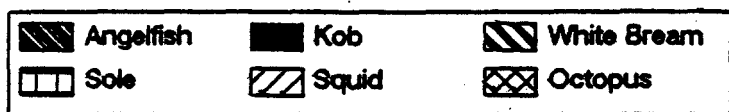
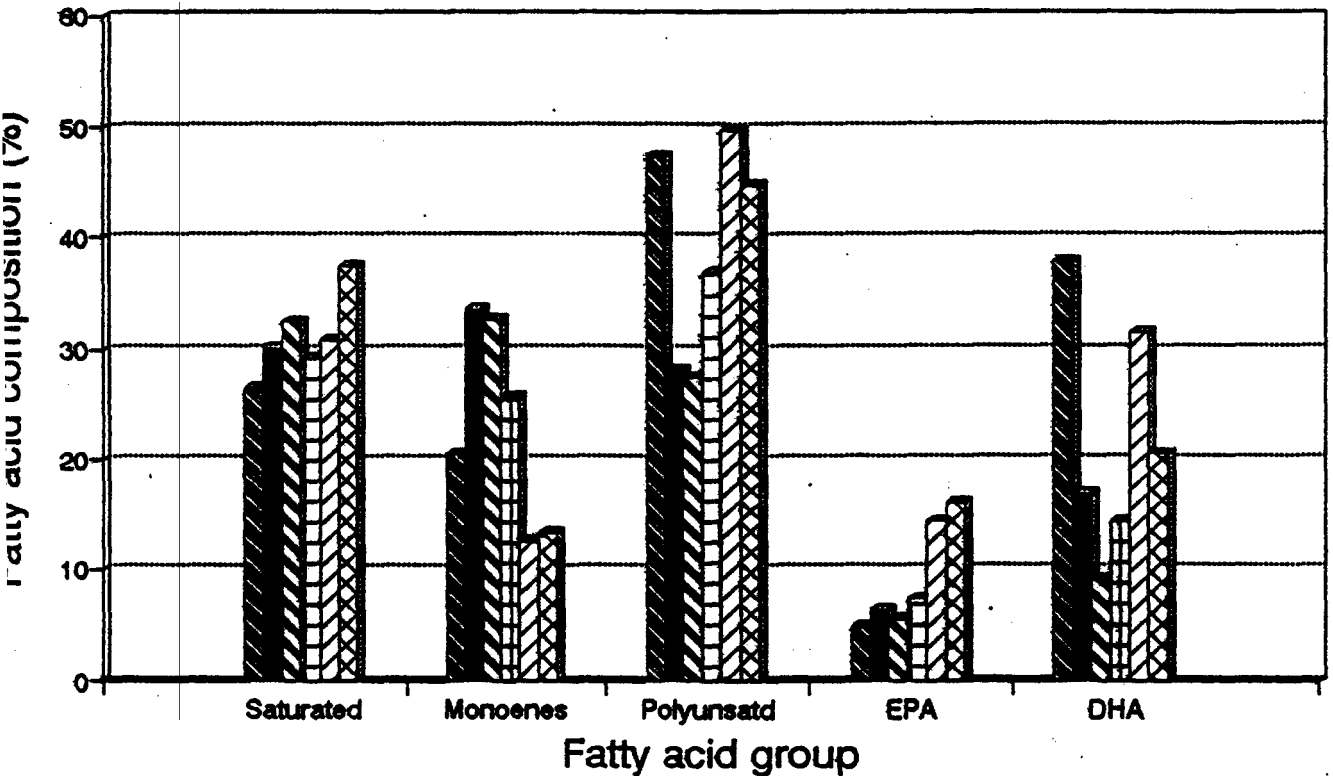
FIGURE 21  
Fatty acid composition of Aegean fish fat





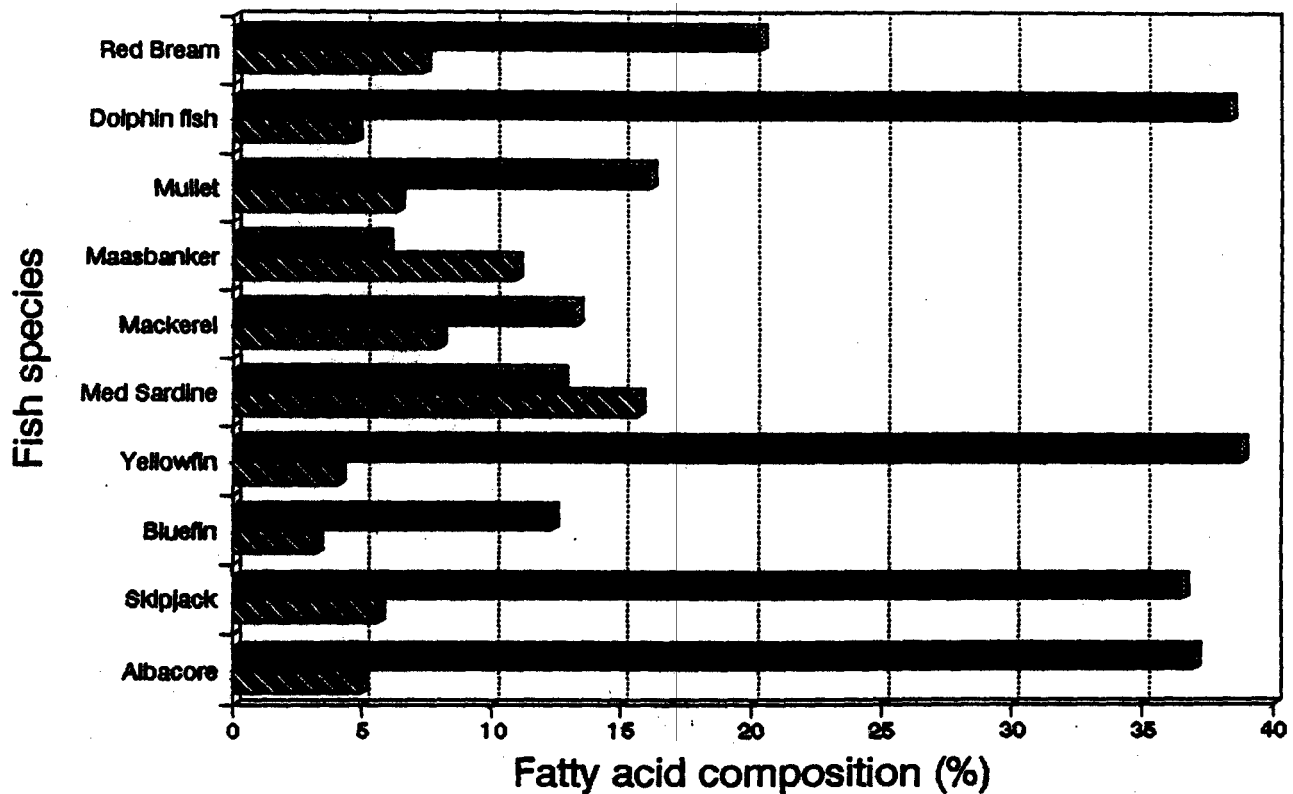
FIGURES 22 & 23



Fatty acid composition of Aegean fish fat

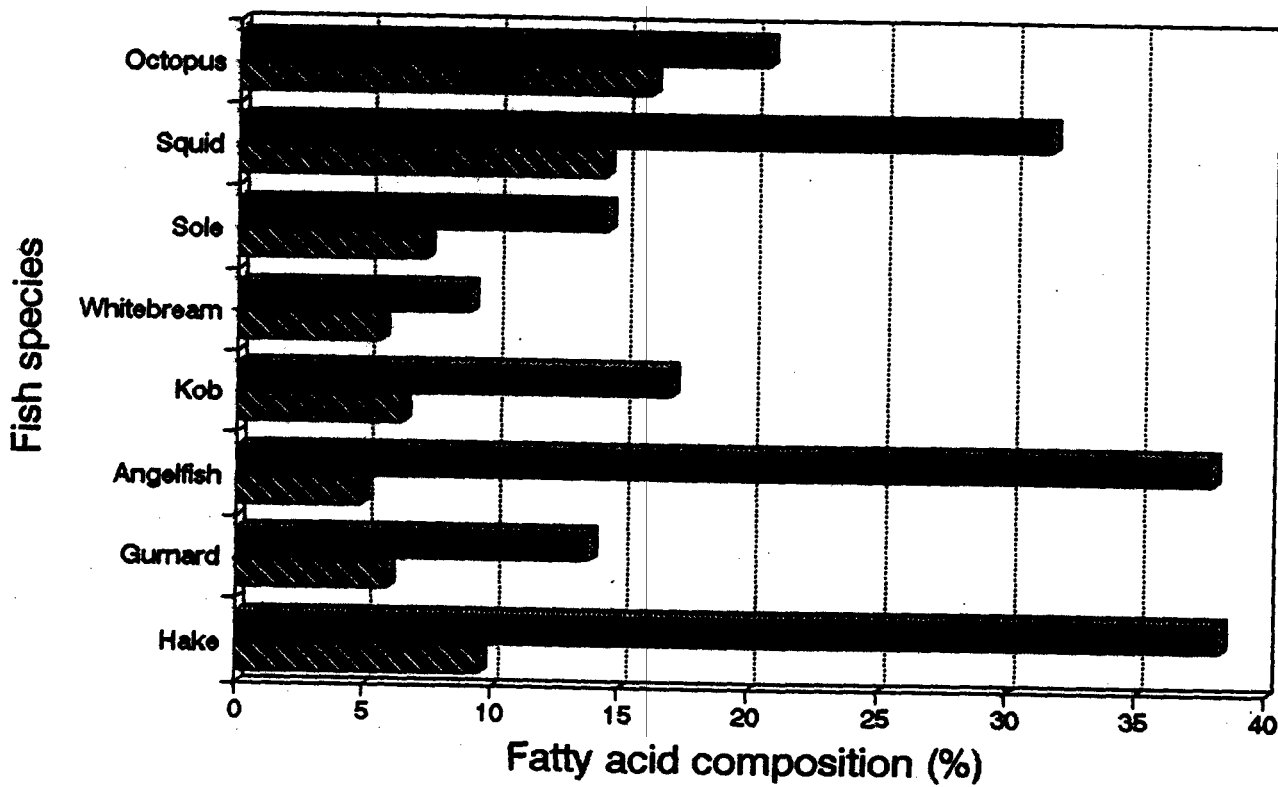


FIGURES 24 & 25

EPA and DHA content of Aegean fish fat



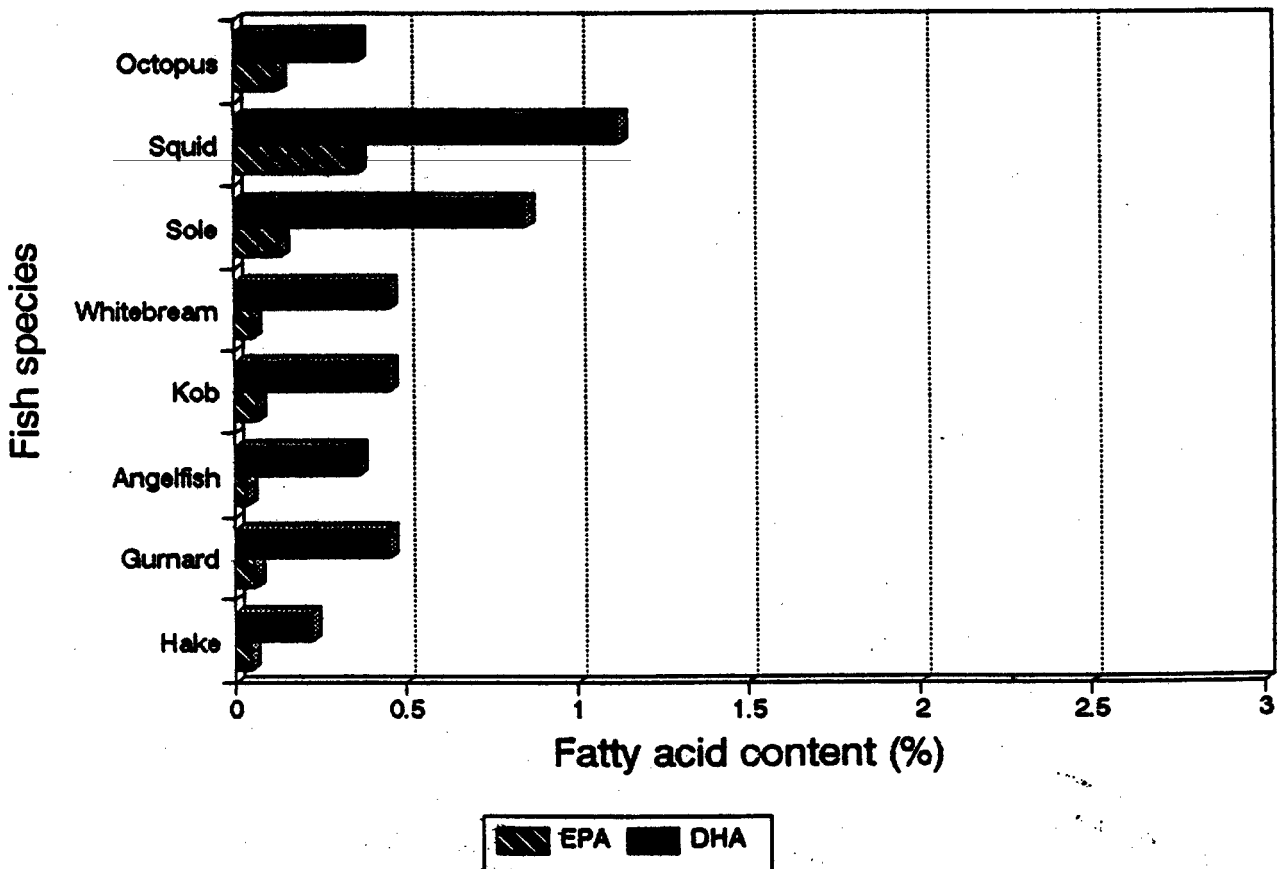
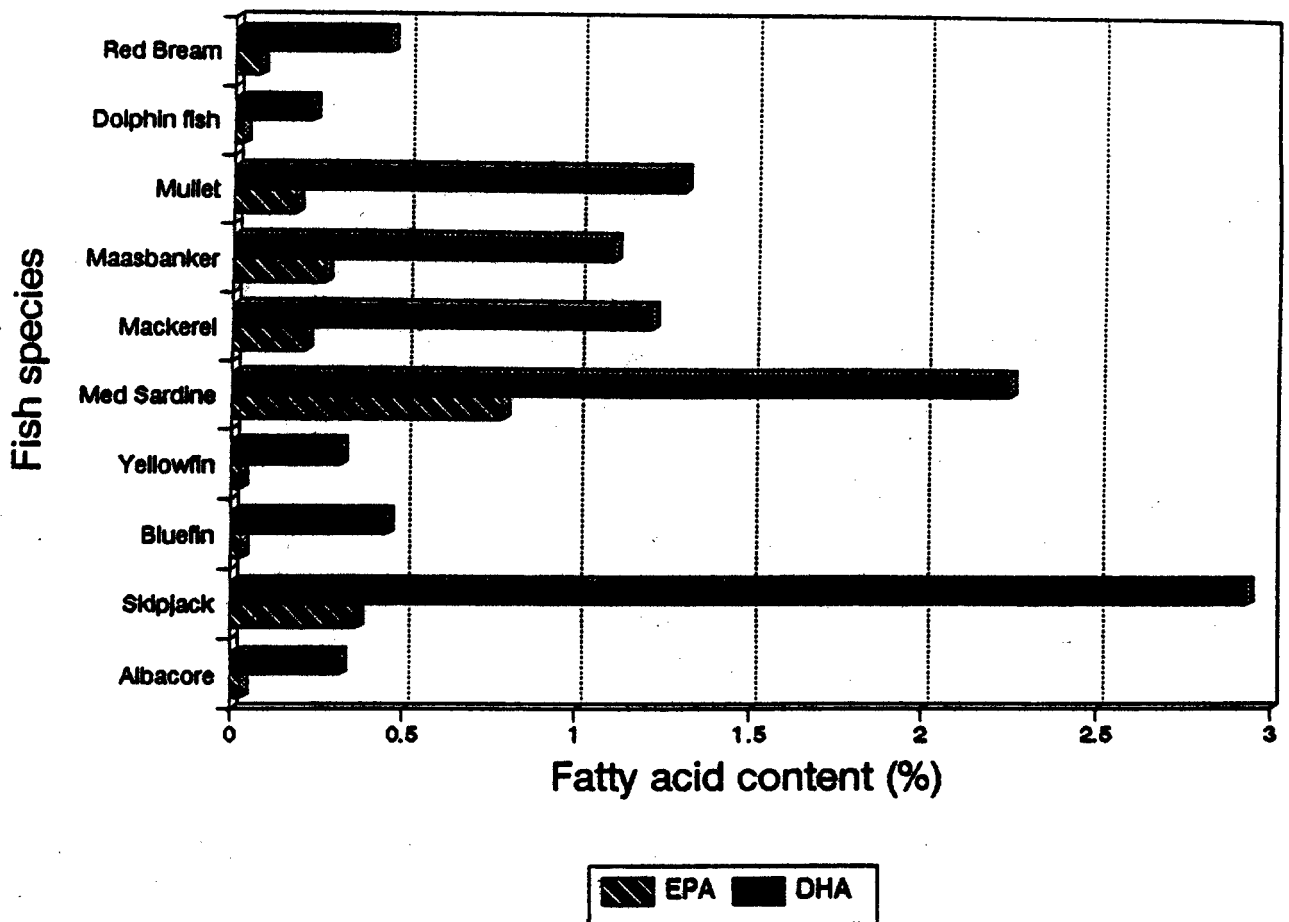
 EPA
  DHA



 EPA
  DHA

FIGURES 26 & 27

EPA and DHA content of Aegean fish flesh



In addition to analyses undertaken by the Fishing Industry Research Institute, Cape Town, other fatty acid analyses have been carried out in Crete and Greece.

Tornaritis *et al* (1993 : 135-139, Table 1) published the fatty acid composition of eight species of Aegean fish, reported to be the most commonly eaten fish on Crete (*ibid* : 137). Six of the fish species were caught 7 km north of Herakleion, Crete. The other two fish, *Pagrus pagrus* and *Sparus aurata* were cultured specimens obtained from the Institute of Marine Biology, Herakleion. Karakoltsidis *et al* (1995 : 268, Table 6) analysed fourteen fish and cephalopods caught in the Aegean for fatty acid composition.

Variations exist in the analytical methods used by the three laboratories. The Fishing Industry Research Institute used the method of De Koning *et al* (1983 : 180), the fat for analysis being extracted from the raw fish. On Crete the University of Crete, Herakleion used the method of Morrison and Smith (1964 : 600-609, *cited* Tornaritis *et al* 1993 : 136). The fatty acids were obtained from the mesenteric fat or from the extracted fat of raw fish. At the Technological Educational Institution, Thessaloniki, Greece, fish were analysed for fatty acids using the method of Kates (1972, *cited* Karakoltsidis *et al* 1995 : 260-261). The lipids were extracted from homogenised edible flesh cut from the fish. Omega-3 fatty acid levels are affected by seasonal variations in fish lipid content. Ackman notes that in fat autumn Atlantic mackerel the lipid content per 100 grams of tissue may be equal in light and dark muscle. In lean spring mackerel the proportions differ (1989 : 169-170, Tables 3 and 5).

The following two tables compare similar fish lipids analysed for EPA and DHA contents at the Fishing Industry Research Institute, Cape Town, the University of Crete, Herakleion, and the Technological Educational Institution, Thessaloniki.

TABLE 33

Lipid analysis: Comparison of EPA and DHA contents (%)  
University of Crete (UOC) and Fishing Industry Research Institute (FIRI)

Fish species	EPA		DHA	
	UOC	FIRI	UOC	FIRI
Mackerel	8,7	7,9	15,4	13,3
Striped mullet	9,8	6,3	2,4	16,1
Hake	4,7	9,5	11,1	38,1
Sea bream	2,3*	7,3	7,6*	20,3

\*Cultured fish

Table 33 shows that the analyses of the lipids for EPA and DHA for mackerel are in good agreement. EPA contents (%) for mullet, hake and sea bream show some disparities. The DHA analyses undertaken by the Fishing Industry Research Institute for mullet, hake and sea bream are noticeably higher than those done by the University of Crete.

Table 34 lists eight species of fish and cephalopods common to the analyses of Karakoltsidis *et al* (1995 : 268-269, Table 6) and the Fishing Industry Research Institute (Tables 28-32).

TABLE 34

Lipid analysis: Comparison of EPA and DHA contents (%)  
Technological Educational Institution, Thessaloniki (TEIT) and  
Fishing Industry Research Institute (FIRI)

Fish species	EPA		DHA	
	TEIT	FIRI	TEIT	FIRI
Skipjack tuna	10,0	5,6	27,0	36,5
Horse mackerel	6,0	10,9	16,0	5,9
Anchovy	11,0	19,6	20,0	9,3
Sardine	4,0	15,7	12,0	12,7
Mackerel	1,0	7,9	4,0	13,3
Sole	8,0	7,3	22,0	14,4
Octopus	18,0	16,1	21,0	20,6
Squid	18,0	14,3	5,0	31,6

Provided allowance is made for variations in the analytical techniques, also possible biochemical and environmental differences, the EPA contents of six of the eight species compare reasonably well. The species are:

	<u>TEIT</u>	<u>FIRI</u>
octopus	18,0	vs 16,1%
squid	18,0	vs 14,3%
sole	8,0	vs 7,3%
horse mackerel	6,0	vs 10,9%
skipjack tuna	10,0	vs 5,6%
anchovy	11,0	vs 19,6%

It should be noted that South African anchovy oil is particularly high in EPA. The Greek anchovy at 11% falls within the variations seen between the South African fish (19,6%) and the north Chilean (10,1%) (see Table 27).

Mackerel (1,0 vs 7,9%) and sardine (4,0 vs 15,7%) show disparities.

Skipjack tuna lipids (27,0 vs 36,5%), sardine lipids (12,0 vs 12,7%) and octopus lipids (21,0 vs 20,6%) show good agreement for DHA contents. Sole has a difference of 7,6%. Squid, mackerel and horse mackerel have greater disparities. The Greek figure for anchovy DHA is unrealistically high (20,0 vs 9,3%), the figure of 20% being about twice that for South Africa, Chile, California and Peru (see Table 27).

Karakoltsidis *et al* (1995 : 271) suggest that their analyses be used with some caution, since they are based on few samples. Notwithstanding this the sets of Cretan and Greek fatty acid analyses provide a useful yardstick against which the South African analyses can be compared.

The analyses taken as a whole generally affirm that the Aegean fish sampled are a good source of *n*-3 dietary fatty acids.

Simopoulos (1990 : 64-76, *cited* Tornaritis *et al* 1993 : 13) suggests that it is nutritionally advantageous to maintain a relatively low dietary ratio of *n*-6 to *n*-3 fatty acids. In the eight fish analysed in Table 34 this ratio varies from 0,2 to 0,7. Inclusion of these fish in the traditional Cretan diet would have helped to maintain low dietary ratios of *n*-6 to *n*-3 polyunsaturated fatty acids.

In the human diet long-chain polyunsaturated fatty acids are obtained almost exclusively from fish or marine mammals. Notwithstanding the demonstrable presence of these important polyunsaturated fatty acids in Aegean fish, together with the current dietary recommendations for the daily intake of DHA + EPA, it is difficult to quantify their intake on Minoan Crete. Apart from fish consumption being higher in coastal areas, intake of these fatty acids is affected by the size and availability of the fishery resource, seasonality and the fish species caught. The following table, which relates to fish consumption for 1988 in the United Kingdom, provides data on the relationship between fish consumption, fish species consumed and the available DHA + EPA.

TABLE 35

*Per capita* intake of fish and related *n*-3 long-chain polyunsaturated fatty acids in the United Kingdom

	Fish consumed (g/day)	Intake EPA + DHA (mg)
*Tuna	2,8	11,2
*Pilchard	0,6	7,8
*Sardine	0,5	6,5
*Mackerel	0,2	2,8
White fish (cod, flat fish)	9,3	23,8

\*Canned fish

Source: Adapted from Barlow and Pike 1991: 2

The table shows that the principal source of marine *n*-3 polyunsaturated fatty acids in the United Kingdom is white fish. This contrasts with Aegean archaeological evidence which indicates that the smaller pelagic species, tuna and some demersal fish were the preferred choice. Barlow and Pike (1991 : 18) suggest that one gram of *n*-3 polyunsaturated fatty acids (DHA + EPA) is required *per capita* per day to satisfy the requirements for an optimum balance of lipids. In the United Kingdom the present dietary consumption of these fatty acids is estimated to be 0,09 gram *per capita* per day (Barlow and Pike 1991 : 19), which is considerably less than the amount recommended.

Tables 36, 37 and 38 are calculated estimates for the content and consumption of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) obtained from different fish species identified archaeologically as caught in the Aegean. The data are based on the traditional fish consumption on Crete, estimated to be 168 grams *per capita* per week (Allbaugh 1953 : 110), in combination with the fatty acid composition analysis for Aegean fish listed in Tables 28-32.

TABLE 36

Fatty acid composition (%) and consumption levels of EPA and DHA  
from Aegean fish based on Ailbaugh (1953)

	Albacore	Skipjack	Bluefin tuna	Yellowfin tuna	Mediterranean sardine	Mackerel
Fat	0,7	6,51	1,0	0,7	5,0	2,7
Protein	25,5	26,7				19,5
Saturated	29,3	30,4	40,7	26,1	34,3	38,8
Monoenes	15,8	3,2	41,2	12,7	20,3	31,3
Polyunsaturated	47,8	60,0	18,0	48,2	41,9	27,6
EPA	4,9	5,6	3,2	4,0	15,7	7,9
DHA	36,9	36,5	12,3	38,7	12,7	13,3
EPA/flesh	0,034	0,365	0,032	0,028	0,785	0,213
DHA/flesh	0,258	2,376	0,123	0,271	0,635	0,359
<b>Total EPA+DHA/flesh</b>	<b>0,293</b>	<b>2,741</b>	<b>0,155</b>	<b>0,299</b>	<b>1,420</b>	<b>0,572</b>
Fish/week (g)	168	168	168	168	168	168
Fat/week (g)	1,18	10,94	1,68	1,18	8,40	4,54
EPA/week (g)	0,06	0,61	0,05	0,05	1,32	0,36
EPA/day (g)	0,01	0,09	0,01	0,01	0,19	0,05
DHA/week (g)	0,43	3,99	0,21	0,46	1,07	0,60
DHA/day (g)	0,06	0,57	0,03	0,07	0,15	0,09
<b>Total EPA+DHA/day</b>	<b>0,07</b>	<b>0,66</b>	<b>0,04</b>	<b>0,07</b>	<b>0,34</b>	<b>0,14</b>

TABLE 37

Fatty acid composition (%) and consumption levels of EPA and DHA  
from Aegean fish based on Ailbaugh (1953)

	Horse mackerel	Mullet	Dolphinfish	Red bream	Hake	Gurnard
Fat	2,45	2,9	0,5	1,0	0,5	1,0
Protein		20,7	22,2		17,0	
Saturated	26,5	29,2	25,7	32,9	25,8	28,8
Monoenes	41,5	40,3	14,9	20,8	15,8	41,4
Polyunsaturated	26,7	29,5	51,8	41,4	53,4	23,1
EPA	10,9	6,3	4,7	7,3	9,5	5,9
DHA	5,9	16,1	38,3	20,3	38,2	13,8
EPA/flesh	0,267	0,182	0,023	0,073	0,047	0,059
DHA/flesh	0,145	0,467	0,192	0,203	0,191	0,138
<b>Total EPA+DHA/flesh</b>	<b>0,412</b>	<b>0,650</b>	<b>0,215</b>	<b>0,276</b>	<b>0,239</b>	<b>0,197</b>
Fish/week (g)	168	168	168	168	168	168
Fat/week (g)	4,12	4,87	0,84	1,68	0,84	1,68
EPA/week (g)	0,45	0,31	0,04	0,12	0,08	0,10
EPA/day (g)	0,06	0,04	0,01	0,02	0,01	0,01
DHA/week (g)	0,74	0,78	0,32	0,34	0,32	0,23
DHA/day (g)	0,03	0,11	0,05	0,05	0,05	0,03
<b>Total EPA+DHA/day</b>	<b>0,10</b>	<b>0,16</b>	<b>0,05</b>	<b>0,07</b>	<b>0,06</b>	<b>0,05</b>

TABLE 38

Fatty acid composition (%) consumption levels of EPA and DHA  
from Aegean fish based on Allbaugh (1953)

	Angelfish	Kob	White bream	Sole	Squid	Octopus
Fat	0,8	1,0	1,0	1,9	2,5	0,8
Protein	22,3			17,4		
Saturated	26,5	30,2	32,6	29,2	30,9	37,5
Monoenes	20,6	33,7	32,8	25,7	12,5	13,4
Polyunsaturated	47,3	28,3	27,6	36,9	49,7	44,8
EPA	4,8	6,4	5,6	7,3	14,3	16,1
DHA	37,9	16,9	9,0	14,4	31,6	20,6
EPA/flesh	0,038	0,064	0,056	0,138	0,357	0,128
DHA/flesh	0,30	0,17	0,09	0,224	0,79	0,165
<b>Total EPA+DHA/flesh</b>	<b>0,342</b>	<b>0,233</b>	<b>0,146</b>	<b>0,412</b>	<b>1,148</b>	<b>0,294</b>
Fish/week (g)	168	168	168	168	168	168
Fat/week (g)	1,34	1,68	1,68	3,19	4,20	1,34
EPA/week (g)	0,06	0,11	0,09	0,23	0,60	0,22
EPA/day (g)	0,01	0,02	0,01	0,03	0,09	0,03
DHA/week (g)	0,51	0,28	0,15	0,46	1,33	0,28
DHA/day (g)	0,07	0,04	0,02	0,07	0,19	0,04
<b>Total EPA+DHA/day</b>	<b>0,08</b>	<b>0,06</b>	<b>0,04</b>	<b>0,10</b>	<b>0,28</b>	<b>0,07</b>

The method of calculation for Tables 36, 37 and 38 can be illustrated by using the Mediterranean skipjack tuna *Katsuwonus pelamis* as an example. The fat content of the tuna analysed was 6.5% and the EPA and DHA contents 5,6% and 36,5% of the total fat respectively. This implies that the whole fish contained an average of 0,36% of EPA and 2,38% of DHA. The total EPA + DHA was 2,74%.

A Cretan eating 168 grams of skipjack per week would consume 10,94 grams of fish oil, this contributing 0,61 grams of EPA and 3,9 grams of DHA, a combined total of 4,51 grams per week, equivalent to 0,66 grams of EPA + DHA per day.

Similar calculations show that Mediterranean sardine *Sardinella aurita*, mackerel *Scomber japonicus*, horse mackerel *Trachurus trachurus* and mullet *Mugil cephalus* provide 0,34, 0,14, 0,10 and 0,16 grams of EPA + DHA respectively on an equivalent daily basis. Squid *Loligo vulgaris* the popular Greek calamari, also on an equivalent basis, provides a *per capita* daily amount of 0,28 grams EPA + DHA. Though these amounts are less than the 1 gram combined EPA + DHA considered to be nutritionally essential by Barlow and Pike (1991 : 18), it

is accepted that even small amounts of fish eaten regularly are nutritionally beneficial (Nestel 1987 : 9-12; Kinsella 1990 : 3). If for example skipjack consumption rose to a more realistic level of 400 grams *per capita* per week, the combined daily EPA + DHA intake would be 1,62 grams, a figure well in excess of the recommended 1 gram.

The analyses demonstrate that the lipid content and composition of the fish consumed is particularly relevant with regard to EPA and DHA. Lean white fish such as the cod eaten in the United Kingdom and northern Europe only contains 1 to 2% fat, of which some 25% of the fatty acid components are *n*-3 polyunsaturated fatty acids. In contrast to this mackerel, anchovy, horse mackerel and tuna, all eaten in the Aegean Bronze Age, contain greater amounts of fat, the levels ranging from 3 to 8%. The fat content would depend on where the flesh eaten was cut from and the season of the year. This suggests that even though the actual *per capita* amount of fish eaten on the Aegean islands and on Minoan Crete is unknown, the species of fish caught and consumed were nutritionally superior to the lean white fish eaten in the United Kingdom.

Clinical and epidemiological studies to be discussed in the next section indicate that islanders and coastal dwellers, who traditionally obtain part of their food from the sea, eat more fish *per capita* than people who live inland. Studies show that Greenland Eskimos derive considerable health benefits from consumption of up to 10 grams per day *per capita* of polyunsaturated fatty acids obtained from fish and marine mammals (Nestel 1987 : 9; Duthie and Barlow 1992 : 26-27). Japanese islanders who consume approximately one gram of *n*-3 polyunsaturated fatty acids obtained from fish derive similar benefits (Kinsella 1990 : 3). The Bronze Age Aegean islanders and the Minoans on Crete, on the basis of nutritional and chemical evidence, probably derived nutritional benefits not too dissimilar to those achieved by the present-day Japanese island fishing community.



Cretan Seal

**6.4 Current research and postulated beneficial health effects of fish fatty acids**  
**(a) Docosahexaenoic acid (DHA)**  
**(b) Eicosapentaenoic acid (EPA)**

Research conducted by the medical profession and fishery scientists particularly within the past decade emphasises the nutritional benefits of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), two fatty acids present in certain common fish. Examples of these fish are found amongst sub-tropical Atlantic species present in the Mediterranean, Aegean and off the southern Cape coast. EPA it is suggested is essential for maintaining the cardiovascular system in healthy shape (Renaud *et al* 1995 : 1360S-1367S; Burr 1989 ; 757-761), while DHA is necessary for the proper functioning of the central nervous system. Of importance is the finding that development of the human brain in the foetus requires DHA, which must be provided by the mother (De Koning 1993 : 1-5; Barlow and Pike 1991 : 19).

Two international conferences, one held in Cape Town in 1991 and the other in Lugano, Switzerland in 1993, highlight the complex relationships that exist between diet, malnutrition and poverty on the one hand and the degree to which a society develops its potential skills and cultural expertise on the other. The case studies presented at these conferences though far removed in time and place from the Aegean Bronze Age are relevant to this study, since they touch on factors that could have contributed to the emergence of the Minoan civilisation on Crete at the end of the third millennium BC.

In Cape Town an unpublished conference paper delivered to the Medical Research Council was related to the endemic South African problems of poverty, malnutrition and social development (Monckeberg 1991). The speaker emphasised that mere expenditure of money associated with economic progress does not remove deprivation and idleness from a society. Quoting Chilean experience over a thirty year period and citing Vial *et al* 1991, he pointed out that poverty and malnutrition were frequently paralleled in a peasant society by a low level of intelligence together with an absence of innovation and skills. He described how in Chile with its large peasant population, a culture of good health had been systematically built up as opposed to periodic welfare handouts. The basis of this health culture was some 1500 clinics where primary health care was practised. Pregnant or weaning mothers were given high quality milk powder in addition to a fortified cereal-based health supplement. This supplement contained a high-protein fish concentrate produced in Chile made from pelagic fish of the pilchard family.

What is clear in this Chilean project, and possibly relevant to the Aegean Bronze Age, is that the large peasant population remained economically poor by Western standards. Because of improved health standards and nutrition however they were now better educated and more able to contribute to the productivity of their communities. Where previously some 73 per cent of villagers were affected by some form of stunted growth this had declined to 8,5 per cent. Infant mortality rates dropped and illiteracy was reduced from 25 to 4 per cent. The importance of early supplementary nutrition at the pre- or post-natal stage was emphasised by poor results obtained in a feeding scheme with 7-9 year old children at a Santiago slum school. At this age nutritional supplementation produced no improvement in scholastic ability or Intelligence Quotients despite overall increases of the pupils in height and weight. Ackman (pers. comm.) suggests that in the feeding scheme referred to there might have been the addition of bovine blood-derived haem-iron to offset anaemia. In this case no effect on Intelligence Quotient would be expected.)

At Lugano this important relationship between pre- and post-natal essential nutrition and later lack of skills and low Intelligence Quotients was again discussed at a conference in 1993 (De Koning 1993 : 1-4). Whereas in Chile emphasis was placed on primary health care, social work and education, at Lugano the dietary importance of lipids and essential fatty acids for optimum infant development was stressed. Speakers emphasised the importance of diet on the development of the foetal brain. A paediatrician described research on the fatty acid composition of the phospholipids from the brains of 17 babies who had died accidentally. His data suggested that for correct development of the foetal brain the fatty acid docosahexaenoic acid (DHA) must be provided by the mother. In addition babies require DHA in their milk for brain development after birth. Examination of the total phospholipids of the infants' brains *post-mortem* showed that the breast-fed infants had greater concentrations of DHA in their lipids than those not breast-fed. The paediatrician suggested that in the absence of *n-3* fatty acids in the diet infants synthesise docosapentaenoic acid (DPA) (C22:5*n-6*) at the expense of DHA (Jamieson *et al* 1993, *cited* De Koning 1993 : 2). The presence of DPA in the brain lipids leads to visual impairment and as a consequence a low Intelligence Quotient and lack of social achievement. Ackman (pers. comm.) notes that the docosapentaenoic acid in fish oils is 22:5*n-3*. The alternate isomer 22:5*n-6* is part of the linoleic acid family and in the brain indicates an omega-3 deficiency.

Two recent studies undertaken on island communities attempted to relate consumption of fish rich in long-chain *n*-3 fatty acids to increased birth weight of infants (Olsen *et al* 1993 : 436-440; Harper *et al* 1991 : 166). The two island communities investigated (the Faroes and the Orkneys) share the isolation and certain other characteristics, notably a reliance on fish and caprini, with Bronze Age Crete. The aim of the Danish research on the Faroes was to investigate whether a raised consumption of seafood might explain the difference in birth weight between babies delivered in the Faroes and others born in Denmark. The study was based on a survey of life-style factors linked to data obtained from antenatal and obstetric records of 1021 island births between March 1986 and December 1987.

The Danish research on a theoretical level was intended to establish whether eating fish rich in long-chain *n*-3 fatty acids may increase birth weight in two ways: (i) whether it would prolong pregnancy by interfering with the prostaglandins involved in the process of parturition, and (ii) if foetal growth could be increased by raising the ratio of biologically active prostacyclins to thromboxanes and reducing blood viscosity, thereby facilitating placental blood flow.

On a seafood diet consisting of fish or whale meat estimated to contain between 0,5 and 1,0 grams of *n*-3 fatty acid content per 100 grams of fish, gestational age, birth weight and birth length tended to increase with the number of seafood meals per week, but only up to a consumption level of three per week. Despite reservations on this research that include the relatively small sample size, the short duration of the study and an absence of specific fatty acid data on the fish, the researchers conclude that the work supports the hypothesis that fish ingested during pregnancy increases the baby's size and that dose response relationship has a saturation level (Olsen *et al* 1993 : 439).

While the weight difference recorded for the Faroese babies averaged 200 grams over those of the mainland, an average difference of 62 grams was reported between the Orkneys and an area on the Scottish mainland. Despite the latter authors' reluctance to accept their findings, based on the differences in known determinants of birth weight rather than raised fish consumption, the data does not negate the possibility that dietary marine *n*-3 fatty acids may prolong pregnancy and hence increase foetal weight (Harper *et al* 1991 : 166).

This emphasis on good nutrition for young expectant mothers, and the necessity to receive sufficient DHA in their diets highlights the possible contribution made by the *n*-3 fatty acids to the nutritional well-being of the Aegean coastal and island communities in the Bronze Age. The analyses of fish species caught in the Aegean show that many of them contained good levels of the fatty acid DHA (Tables 28-32).

The possible importance of DHA in early development of the brain was also referred to at the Lugano conference mentioned earlier by another speaker, a physician who suggested that if DHA is not provided in the diet, alternative docosapentaenoic acid (DPA) is found in the brain. This leads to a loss of photoreceptive response, consequent learning disorders and later, absence of skills. Discussing the chemical structure of DHA and DPA the speaker indicated that there is a difference of only one double bond in these two compounds, but neurologically the two compounds are entirely different (Salem 1993, *cited* De Koning 1993 : 3).

In another paper by American and Chilean researchers the necessity for correct infant nutrition was once more emphasised and the effect that a lack of DHA has on the infant's visual response stressed. In a feeding trial in which infants were fed either a diet containing corn oil (C18:2*n*-6), soybean oil (C18:3*n*-3) or soybean oil to which fish oil was added to provide 0,4% DHA, the infants were tested for visual response at 36 and 57 weeks after conception. The group of infants fed the diet in which fish oil was added to the soybean oil had the highest visual response. This response was similar to infants fed on mother's milk that contained natural DHA. In yet another infant feeding trial the same Chilean and American researchers compared the visual response at three years of breast-fed and formula-fed infants. Babies fed mother's milk containing natural DHA performed visual recognition tasks significantly better than infants fed the formulated baby food. The results of these two infant feeding trials demonstrated the nutritional importance of long-chain *n*-3 fatty acids of which fish is an important source in early human nutrition (Uauy *et al* 1993, *cited* De Koning 1993 : 3-4).]

Independent research carried out in Chile, Scotland and the United States of America indicates a possible relationship between diet, nutrition and the docosahexaenoic acid (DHA) content of the brain and retina and the development of intelligence (Monckeberg 1991; De Koning 1993 : 1-4; Vial *et al* 1991 : 389-397). The research projects described so far were

essentially comparative in design, and intended to determine the effects of the presence or absence of DHA on the development of the foetal and infant brain.

Publications on the effects of DHA are noteworthy for the multi-disciplinary nature of the research. Participants range from nutritionists to paediatricians and clinical physicians to biochemists, lipid chemists and archaeologists. Apart from the comparative qualitative studies on human infants, more technically complex research has also been undertaken using laboratory animals in attempts to clarify the underlying nature of the DHA phenomenon. Experimental work with animals has shown for instance that prolonged dietary deficiency of *n*-3 fatty acids may result in decreased DHA levels in the brain and retina and impairment of the normal vision of rats and monkeys (Benolken, Anderson and Wheeler 1973 : 1253-1254; Connor and Neuringer 1988 : 275-294).

Biochemists suggest that DHA is synthesised in the liver and/or brain from the essential fatty acid  $\alpha$ -linolenic acid (C18:3*n*-3). To test the hypothesis Arbuckle and Innis (1992 : 91-93) fed fish oil to piglets in diets that contained known amounts of  $\alpha$ -linolenic acid. These test diets were fed from birth to 15 days and contained either high or low amounts of  $\alpha$ -linolenic acid, or alternatively a low content of linolenic acid supplemented by fish oil, calculated to provide C20 and C22 *n*-3 polyunsaturated fatty acids at a level of 0,8% of the total fatty acids. *Post-mortem* analysis of developing brain and retinal tissue showed  $\alpha$ -linolenic acid as the only *n*-3 fatty acid that supported deposition of DHA at a level that was comparable to natural milk. When fish oil was added as a supplement (0,4 Kcal) to a low level of  $\alpha$ -linolenic acid (C18:3*n*-3), the analysis showed that the DHA content of the tissue was again comparable with natural milk. The results of this experimental work indicate that  $\alpha$ -linolenic acid can be effectively converted into EPA and DHA by the human body if the appropriate enzymes are present (see Table 40).

In another animal experiment researchers in Switzerland used laboratory rats to combine chemical studies on the effect of a low intake of *n*-3 fatty acids on brain development with an investigation into the exploratory behaviour of the animals (Enslin, Milon and Malnoë 1991 : 203-207). Female rats were fed diets containing safflower oil or soybean oil for six weeks prior to mating and through gestation and lactation. The behavioural studies and *post-mortem* phospholipid analyses on the rats progeny were carried out at 16 to 18 weeks after birth. The phospholipids analysed (phosphatidyl choline and phosphatidyl ethanolamine) are reported to be

the main phospholipids in the brain. Decreased levels of C22:6 $n$ -3 in the phospholipids were observed in the rats fed safflower oil. The results of this work suggest that a lack of  $n$ -3 fatty acids during pregnancy and development causes profound modifications of the fatty acid composition of brain phospholipids. The biochemical changes were associated with alterations to the exploratory behaviour of the rats and the authors suggest that these behavioural changes could have been due to alterations in sensory perception.

With regard to the validity of the above research, Connor and Neuringer (1988 : 275-294) point out that the visual system of rats differs in many ways from that of humans. These authors therefore chose to study the effects of  $n$ -3 fatty acid deficiency of the retina on a higher primate species which more closely resembles the human in its retinal anatomy, visual capacities and nutritional requirements. The blood plasma and tissue of Rhesus monkeys were studied after a combination of maternal and post-natal deprivation of dietary  $n$ -3 fatty acids. Throughout pregnancy adult female Rhesus monkeys received a diet with safflower oil as the only fat. The infant monkeys were hand-reared and received a similar diet to that of their mothers from birth, the diet containing less than 0,3% of total fatty acids as  $\alpha$ -linolenic acid (C18:3 $n$ -3). The mothers and infants in the control group received a diet with soybean oil as the fat source that provided 7,7% of total fatty acids as  $\alpha$ -linolenic acid.

The results of this feeding trial using Rhesus monkeys fed an  $n$ -3 fatty acid deficient diet revealed a deficiency of DHA as well as a lack of visual acuity. At 24 weeks after birth DHA was barely detectable in the plasma phospholipids of the  $n$ -3 deficient animals; DHA levels in the retina were reduced by 50% and by 75% in the cerebral cortex. In the control infant monkeys fed soybean oil the proportion of DHA in both blood plasma and the cerebral cortex doubled between birth and 22 months. At 22 months the DHA levels in the  $n$ -3 deficient monkeys was reduced by 80-85%. The visual acuity of the DHA deficient infant Rhesus monkeys was reduced by half at 8 and 12 months of age (refer Connor and Neuringer 1988 : 275-294, Fig. 7). This lack of visual perception was accompanied by a number of abnormalities that were detectable by electroretinogram.

To test the reversibility of the DHA deficiency five of the deficient progeny were fed  $n$ -3 rich fish oil, beginning at 10-24 months of age. The fish oil replaced 80% of the safflower oil.

After dietary repletion with fish oil the changes in fatty acid composition were rapidly reversed, the levels of DHA and EPA C20:5 $n$ -3 in fact increasing above the control values obtained from the soybean oil fed animals. These rapid changes may relate to erythrocytes rather than the brain where lipid turnover is very low (Ackman, pers. comm.). Particularly significant is the fact that despite this increase of DHA no improvement was detected in visual acuity. The failure of fish oil supplementation to restore the functional properties of the retina despite satisfactory levels of DHA suggests that the effects of  $n$ -3 fatty acid depletion during retinal development are irreversible. This may support the empirical findings of Monckeberg in Chile (Monckeberg 1991; Vial *et al* 1991 : 389-397), who found that supplementary feeding at the 7-9 age level to children nutritionally deprived at the pre- and post-natal stage produced negative results.

The work described above together with that referred to earlier undertaken using laboratory rats confirms that an  $n$ -3 deficient diet leads to abnormalities in the retinal potential evoked by light stimulation. The high concentrations of DHA normally found in the photo-receptor membranes appear necessary for the retina to produce a normal electroretinogram and to recover this ability after light stimulation (Connor and Neuringer 1988 : 275-294). Neuringer and Connor point out that the biochemical process is not well understood. Clarification requires an understanding of how DHA in membrane phospholipids helps to create the optimal functional properties of the membrane.

Harris (1996 : 243-252) suggests that confusion has crept into the literature because of the extrapolation of animal data to the human situation. He points out that though animal experiments are useful in sorting out the mechanisms of action, the significance of animal data to human metabolism becomes unclear when the effects seen in humans cannot be reproduced in the animal model. Incompatibility between animal and human responses to  $n$ -3 fatty acid feeding is due to several factors. These include a marked difference in lipoprotein metabolism, differences in oxidative stress and the use of high intakes of  $n$ -3 fatty acid in animal studies. These differences must be taken into account when using animals to study the effects of  $n$ -3 fatty acid on lipoprotein metabolism.

To summarise the evidence. Recent conference reports and publications confirm the nutritional importance of the  $n$ -3 fatty acids for the normal growth and function of the brain. Biochemical analyses, as well as tests on visual perception, indicate that deprivation of DHA in

the brain and retinal tissues of humans, Rhesus monkeys, piglets and Sprague Dawley rats can lead to visual abnormalities and loss of visual and sensory perception. These visual abnormalities and the accompanying learning disabilities and loss of skills appear irreversible, notwithstanding that it is possible by feeding with *n*-3 fatty acid rich fish oil to raise the DHA content of the brain and retinal tissues to normal or even higher levels. Supporting evidence for this irreversibility of brain and retinal dysfunction is provided by Crawford *et al* (1976 : 452-453), who demonstrated that one-half of the DHA required for normal brain development must be obtained *in utero* from the mother. The other half of the required DHA must be obtained from the diet during the first 6 to 12 months after birth.

It has been suggested that the abnormalities in visual function that result from a dietary deficiency of the *n*-3 fatty acids, in particular docosahexaenoic acid and  $\alpha$ -linolenic acid, provide the strongest evidence at present available for the nutritional essentiality of the *n*-3 series of fatty acids (Connor and Neuringer 1988 : 275-294).

Professor Alexander Leaf of the Harvard Medical School, however, emphasises the importance of research on the DHA fatty acid. He maintains that the realisation of the essential nature of C22:6*n*-3 for the normal growth and function of the brain is a most significant finding. Leaf suggests that a deficiency of DHA, with its associated absence of foetal and post-natal brain and retinal development, has its origins in dietary and nutritional changes that have taken place over many millennia. These alterations in the pattern of food consumption and associated nutrition were brought about principally by the transition from Palaeolithic hunter-gathering to agriculture and pastoralism, and again from farming to industrialised urban man (Eaton and Konnor 1985 : 283-289; Leaf and Weber 1988 : 549-557; Leaf 1993 : 1-4).

Discussion so far has emphasised the nutritional value of traditional Mediterranean diets in both general and more specific terms. A diet that is low in saturated fat and animal protein but rich in carbohydrates should contribute to good health and longevity. More specifically the essential fatty acid docosahexaenoic acid (DHA) is shown to be a requirement both in humans and in animals for pre- and post-natal development of the foetal brain. Analyses show that in the Aegean DHA is present at different levels in a variety of sub-tropical Atlantic species of fish and cephalopods. Apart from the importance to Minoan nutrition of a high cereal content obtained from wheat and barley and satisfactory levels of DHA available from certain fish, it is necessary

to discuss briefly a third factor of nutritional importance in the traditional Aegean Bronze Age diets, this being the eicosapentaenoic acid (EPA) content of the Aegean fish catches.

In general terms fish that have a more muscular structure such as the Mediterranean albacore tuna *Thunnus alalunga* and the dolphin fish *Coryphaena hippurus* have high levels of DHA (36,9 and 38,3% of the oils respectively). These fish which usually make particularly good eating generally have lower levels of the other nutritionally important essential fatty acid EPA. The more oily fish such as the Mediterranean sardine *Sardinella aurita* and horse mackerel *Trachurus trachurus* have higher EPA contents (15,7 and 10,9% of the oils respectively) associated with lower DHA contents. High EPA means low DHA and vice versa, seems relatively constant (De Koning 1994 : 352-356).

Since World War II attention has focused on the value of fish oil as a means of minimising certain diseases that include arthritis, rheumatism and in particular coronary heart disease. Attention in the past has been directed primarily towards the value of the essential fatty acid eicosapentaenoic acid (EPA), which is present in the lipids of certain oily pelagic fish such as the pilchard *Sardinops ocellata* at levels of up to 20%. The earliest documented research on the efficiency of fish oil on disease was carried out in 1772 by Dr Kay a physician at Manchester Hospital who prescribed the use of cod-liver oil for the treatment of rheumatism. This research was continued for ten years and the successful results published by Thomas Percival in the London Medical Journal in 1783. In spite of encouraging results in the treatment of rheumatism the work was almost completely forgotten, probably partly due to the unpalatability of the cod-liver oil used which had been crudely extracted. Fish oil was also used for medical purposes involving conditions such as night blindness and rickets long before anything was known about vitamins.

The first suspicion that the consumption of fish in the diet might be beneficial in reducing the incidence of atherosclerosis or other cardiac diseases occurred during the German occupation of Norway in World War II. Strøm (1948 : 126-129), Burr (1989 : 292-293) and other researchers showed that the Norwegian diet had changed substantially during the occupation period and that fish, skimmed milk and cereals had replaced red meat, eggs, wholemilk, cream cheese and fats such as margarine. A study of 40 families in Oslo showed a decline in mean daily fat intake from 159 to 71 grams, and an increase in fish (particularly fatty fish) from 99 to 292

g/day (*ibid* : 293). It was shown that if the average rate of heart fatalities from 1927 to 1940 was arbitrarily indicated as 100, then the rate from 1941 to 1946 was 78,8. After 1946 the rate increased reaching 87,5 by the end of 1948. Based on the statistics available it was impossible to determine however just what caused the reduction in fatal heart attacks. In the 1940's the relationship between high serum cholesterol levels and heart attacks was however known, also that high cholesterol levels could be decreased by the consumption of polyunsaturated vegetable oils.

Fish oils that were known to contain both saturated and polyunsaturated fatty acids were assumed at this time to have no therapeutic value.

The first long-term research on the therapeutic value of fish oil related to heart attacks was carried out between 1952 and 1971 by Dr Averly Nelson of Seattle. Nelson's patients had all had at least one heart attack and about 40% of them were willing to adopt a diet for between 16 and 19 years duration that included fish as a main course at least three times a week (Nelson 1972 : 103-116).

Table 39 contains the results of this dietary study involving a long-term high fish diet.

TABLE 39

Survival of heart disease patients over 16 to 19 years.  
Comparison of those on a standard diet with those on a special diet  
which included fish as a main course at least three times per week

Diet	No. of patients	Per cent surviving
<b>Overall results:</b>		
Standard diet	126	8
High fish diet	80	36
<b>Results for patients 56-70 years of age:</b>		
Standard diet	85	5
High fish diet	44	32

Source: Stansby 1990 Nutritional Properties of Fish Oil for Human Consumption

Nelson's dietary recommendations were innovative in 1952 as there was no evidence that fish oil which contained polyunsaturated as well as saturated fatty acids would be of value in lowering serum cholesterol levels. It was only in 1955 that Bronte-Stewart and others working at the University of Cape Town Medical School confirmed that fish oils were actually considerably more efficient in lowering serum cholesterol levels than were vegetable oils

(Bronte-Stewart *et al* 1956 : 521-530). It is noteworthy, bearing in mind the traditional Aegean diet, that in addition to his recommendation of fish three times a week, Nelson prescribed a low saturated fat, high cereal diet not too dissimilar to the Mediterranean diet discussed earlier.

Nelson's recommended diet contained the following:

- Milk and cheese consumption should be low.
- Meat, lean beef, lamb, veal, chicken or turkey should be restricted to 6 oz per day.
- Fish had no limitation.
- Dark green or yellow vegetables, tomatoes or citrus fruit should be eaten daily.
- Enriched or whole-grain bread or cereals should be eaten three times per day.
- Only three tablespoons of saturated fat, including cooking fat, was permitted each day.
- The diet consisted of about 22% protein, 24% fat and 54% carbohydrate. The protein content could be increased by low-fat seafood, low-fat milk powder, gelatine, defatted wheat germ or eggwhites.

Lacking the analytical techniques that are available today (that produce results such as the fatty acid composition tables that form part of this study), it was impossible to estimate accurately the effect of the seafood component in the above diet. There is little doubt however that the overall diet recommended by Nelson played a major role in the reduction of fatal heart attacks during the 16-19 years of the experiment.

One other long-term study on the effects of a fish diet on coronary disease has been published. This research was carried out in the town of Zutphen, Holland between 1960 and 1980 (Kromhout *et al* 1985 : 1206-1209). In Zutphen 872 men who had never had a heart attack (age 40-59 years) were divided into five groups on the basis of their daily consumption of fish. The groupings comprised 0, 1-14, 15-29, 30-45 and over 45 grams fish/day. The fish eaten comprised two-thirds lean fish and one-third fatty fish. After 20 years the number of deaths from coronary heart attacks was recorded. The analysis showed that 2.5 times as many men who ate no fish died of heart attacks compared to those who ate 45 grams or more per day.

The study of changes in fat, fish and fibre intake on death and myocardial re-infarction undertaken by Burr over a two year period were referred to earlier. In this study 300 grams of

oily fish weekly (2,5 g EPA) reduced mortality (Burr 1989 : 291-316; Burr *et al* 1989 : 757-761; Burr 1995 : 1152-1154).

Comparison between the long-term research of Nelson and Kromhout is difficult since the American patients had all suffered at least one heart attack. The statistics indicate however that for the Dutch eating no fish the incidence of fatal heart attacks was greater than for those eating 45 grams/day of fish. In the American study the corresponding figure for cardiac deaths is four times. In the American research fish consumption was higher, about 60 grams/day, and all the fish was fatty fish of the pilchard/sardine variety. This suggests that the quantity of fish oil containing the medically beneficial fatty acids consumed in the American study was greater than in the Dutch work. (Ackman (pers. comm.) points out that Pacific salmon are often used in American diet studies conducted on the west coast.) If it is assumed that lean fish averaged 1,4% fat and the fatty fish 7%, the amount of fat consumed would be in the ratio 420:150 or almost three times for the American patients as against the Dutch participants.

The two long-term dietary investigations, even though they differed in procedural methods, do indicate that regular fish consumption can reduce coronary heart attacks. The results suggest too that maritime communities, such as those of the prehistoric Aegean, had the advantage of a readily available primary food resource as well as a nutritional supplement beneficial to health. It was in fact this connection between the cardiac health of a maritime community and a high fish diet that gave the clue as to why fish consumption reduces deaths from coronary heart attacks. In the 1970's Dyerberg *et al* (1975 : 958-966) and Bang *et al* (1976 : 69-73) published their epidemiological studies on the low incidence of atherosclerosis among the Eskimos of Greenland. Their statistics showed that age-adjusted mortality among the Greenland Eskimos was approximately one-tenth of that of the Danes or North Americans, despite a diet with fat and cholesterol contents as high as the Danes and the Americans (Kromann and Green 1980 : 401-406). The reason for the low level of coronary deaths amongst the Eskimos, it was suggested, lay in the composition of the fats consumed, the Danish diet containing twice as much saturated fat and more *n-6* polyunsaturated fatty acids than the Eskimo diet.

An average fish or marine mammal consumption of 400 grams/day is reported for the Greenland Eskimos (Nestel 1987 : 9). Quantitatively it is suggested that the Greenland Eskimos consumed between 5 and 10 grams of the nutritionally essential *n-3* polyunsaturated fatty acids

each day. These essential fatty acids (DHA C22:6 $n$ -3 and EPA C20:5 $n$ -3) enter the food chain through marine phytoplankton which are eaten by fish. In the case of the Eskimos, the seals, walrus and whales which consumed these fish would also be eaten by the Eskimos.

As is generally true of many epidemiological studies, an association and not causation was demonstrated by Dyerberg and Bang (1975 : 958-966), since there are many cultural, environmental and genetic differences between Eskimos and Danes. Nevertheless their work stimulated a number of biochemical and physiological studies as well as further clinical trials that were intended to clarify the relationship between a high fish diet and the content of  $n$ -3 fatty acids, and in particular the role of EPA in reducing deaths from coronary heart attacks. In the case of the Eskimos and other maritime communities immunity or reduction from coronary heart disease stemmed from a freedom from thrombosis due to the presence of the fatty acid EPA in their marine diet.

Eicosapentaenoic acid (EPA) is an essential fatty acid, so named because it cannot be made in the body and has to be ingested. The desaturation of an essential fatty acid is very slow in nature and relies, as shown in Table 40, on enzymes (desaturase - delta-6 and delta-5). These convert the common essential fatty acid linoleic acid (found for example in vegetable oils) of the  $n$ -6 series, and  $\alpha$ -linolenic acid of the  $n$ -3 series, through to their respective long-chain essential fatty acids. The essential fatty acids are identified by having their double bonds at the 3rd or 6th carbon interval from the methyl end. Hence  $n$ -6 linoleic acid is 18:2 $n$ -6, where there are 18 carbon atoms, 2 double bonds and the first double bond starts at the  $n$ -6th carbon from the methyl end. Eicosapentaenoic acid (EPA) is 20:5 $n$ -3, twenty carbon atoms, 5 double bonds and the first double bond starts at the 3rd carbon from the methyl end. (See also 3.2 above.)

Walsh (1990 : 135-139) has published the following table to explain the biochemical changes that result in the availability of EPA and DHA.

TABLE 40

The *n*-6 and *n*-3 long-chain polyunsaturated fatty acids

	Essential fatty acids (EFAs)		
	<i>n</i> -6	<i>n</i> -3	
Linoleic (LA)	18:2 <i>n</i> -6	18:3 <i>n</i> -3	Alpha-linolenic (ALA)
	delta-6-desaturase		
Gamma-linolenic (GLA)	18:3 <i>n</i> -6	18:4 <i>n</i> -3	
	elongase		
Dihomogamma-linolenic (DGLA)	20:3 <i>n</i> -6	20:4 <i>n</i> -3	
	delta-5-desaturase		
Arachidonic (AA)	20:4 <i>n</i> -6	20:5 <i>n</i> -3	Eicosapentaenoic (EPA)
	elongase		
Adrenic	22:4 <i>n</i> -6	22:5 <i>n</i> -3	
	delta-4-desaturase		
	22:5 <i>n</i> -6	22:6 <i>n</i> -3	Docosahexaenoic (DHA)

Source: Walsh 1990 : 136

The writer is grateful to Dr Ackman (pers. comm.) for referring to the so-called Sprecher shunt (Voss *et al* 1991, 1995), which should be incorporated in the above table. Since there is no delta-4-desaturase the formation of 22:6*n*-3 takes place via 24:6*n*-3 in the following manner:



Before 1956 no trials had apparently been carried out to determine quantitatively the effect of consuming fish or fish oil on serum cholesterol levels, a factor associated with heart attacks. As a result of the publication of Bronte-Stewart's work in 1956 (521-530) which demonstrated that fish oils were effective in lowering serum cholesterol levels research became more fish oil orientated. During the next ten years many species of fish were shown to possess lipids that had cholesterol-reducing properties. Some of these fish are listed in Tables 41 and 42.

TABLE 41

Species of common fish for which a cholesterol depressant effect has been demonstrated

Species	Source of oil	Reference
Cod	liver	Hauge & Nicolaysen 1959; Howe & Bosshardt 1962 A,B Kahn <i>et al</i> 1963; Kingsbury <i>et al</i> 1961
Cuttlefish	liver	Kaneda & Alfin-Slater 1963
Dogfish	liver	Peifer <i>et al</i> 1965; Wood <i>et al</i> 1961
Halibut	liver	Wood <i>et al</i> 1961
Menhaden	whole fish	Ahrens <i>et al</i> 1959; Peifer <i>et al</i> 1960, 1962, 1965
Mullet	body	Peifer <i>et al</i> 1962
Ocean perch	body	Peifer <i>et al</i> 1962
Pilchard	body	Bronte-Stewart <i>et al</i> 1956
Salmon (coho)	body	Peifer <i>et al</i> 1962
Sardine	body	Miller <i>et al</i> 1962
Seal	body	Bronte-Stewart <i>et al</i> 1956
Tuna	whole fish	Peifer <i>et al</i> 1960
Whale	body	Malmros & Wigand 1957

Source: Stansby 1990, Nutritional Properties of fish Oils for Human Consumption, 278

Table 42 contains the *n*-3 fatty acid content of some common species of fish and crustacea.

TABLE 42

The *n*-3 fatty acid content of some marine fish and crustacea

Species	<i>n</i> -3 Fatty acids g/100 g*
Mackerel	2,5
Trout, lake	1,6
Trout, rainbow	0,5
Herring, Atlantic	1,6
Sardine, canned	1,7
Tuna, albacore	1,3
Tuna, unspecified	0,5
Salmon, chinook	1,4
Salmon, Atlantic	1,2
Bluefish	1,2
Oyster, European	0,5
Crab	0,4
Shrimp	0,4
Cod, Atlantic	0,3
Swordfish	0,2
Lobster	0,2

\*Denotes the number of grams of *n*-3 fatty acids (long-chain C20 and C22) per 100 grams of the raw edible portion of the food source.

Source: Leaf &amp; Weber 1988 : 555

It should be noted that Tables 41 and 42 list at least 10 species of fish or marine mammals as having an *n*-3 fatty acid content or cholesterol depressant effect. Many of these fish are included in the archaeological evidence and analyses that form part of this study.

As with research on the requirement of DHA for foetal brain development where animal experiments using rats, piglets and Rhesus monkeys were carried out concurrently with research on humans, so in the 1960's was similar research undertaken using animals to investigate the beneficial effects of EPA. Peifer (1967 : 322-361) determined the efficacy of fish oil to lower the serum cholesterol level in rats which in most instances were given a pre-treatment diet consisting of 10% tallow plus 0,5% cholesterol and 0,5% cholate. This raised the animal's cholesterol level prior to testing the effects of a fish oil diet. Peifer's research significantly included comparative feeding trials on rats using both extracted fish oil and fish flesh containing the oil, the results showing that the change in serum lipids was about the same (see Stansby 1990, Table 10-3).

The fish species analysed by Peifer (see Table 41) included menhaden, silver salmon and two species found in the Mediterranean and Aegean, mullet *Mugil cephalus* and ocean perch *Sebastes marinus*. Menhaden, silver salmon and mullet are reasonably oily fish but perch is of a low oil content. Yet even in the case of the perch where less than half as much oil was available, approximately the same change in the rats' serum lipids occurred. Feeding rats fish from which the oil had been extracted produced no effect. It is noteworthy that rats fed fish oil showed an immediate reduction in serum cholesterol levels. This effect contrasts sharply with that produced when rats were fed linoleic or linolenic fatty acid, which resulted in a two-week long phase before the serum cholesterol levels started to drop. Bearing in mind Table 40 which illustrates the biochemical changes by which EPA becomes available from  $\alpha$ -linolenic acid, the above experiment suggests that the *n*-3 fatty acids are more rapidly available biochemically from actual fish oil than from *n*-3  $\alpha$ -linolenic acid which requires desaturation to EPA.

A study undertaken in Japan intended to obtain information on the relationship between dietary ingestion of EPA and the incidence of coronary disease, has a bearing on the health of traditional maritime communities such as Crete and the Cycladic islands (Hirai *et al* 1987 : 9-24). In a situation analogous to that of the Greenland Eskimo diet and its effect on heart disease, families of Japanese fishermen living on the coast had a decreased incidence of coronary disease. Associated with reduced cardiac disease was a high consumption of fish. Individuals living in the

fishing village consumed 2,6 grams EPA per day, compared to farmers in an inland settlement who consumed about 0,9 grams of EPA per day. The average deaths from coronary disease were considerably higher in the farming village than in the fishing village.

Earlier studies on the beneficial effects of fish or fish oils on heart attacks generally interpreted the results in terms of the *n*-3 fatty acids collectively, i.e. there was little attempt to distinguish between EPA and DHA. More recent short-term studies have been carried out giving patients concentrated ethyl esters of either EPA or DHA (Terano *et al* 1983 : 321-331; Von Schacky and Weber 1985 : 2446-2450). The research suggests that both EPA and DHA contribute to antithrombotic action, probably through different mechanisms with DHA the less effective. The studies confirm that where the consumption of fish was two to three times greater than that of an inland village, the mortality rate due to ischaemic heart disease and cerebrovascular disease is correspondingly lower.

Another clinical study also carried out in Japan entailed making a highly concentrated eicosapentaenoic acid ethyl ester (EPA-E) from sardine oil. This was fed to 62 patients (average age 59 years) who were suffering from various cerebrovascular and coronary diseases (Stansby 1990). The study was carried out over a 16-week period with daily doses of EPA fed at levels between 1,8 and 2,7 grams per day, depending upon the body weight of the patient. This trial indicated that 1,8 grams/day of EPA can suppress platelet function, such as platelet aggregation. The minimum time for an intake of EPA to achieve this result was four weeks.

Research on the beneficial effects of the *n*-3 fatty acids present in fish oils on heart disease is well documented and there can be very little doubt that such a relationship exists (Nestel 1987 : 9-12; Burr 1989 : 291-316; Duthie and Barlow 1992 : 20-36). The *n*-3 fatty acids give rise to different families of so-called eicosanoids. These eicosanoids are regulators of different biological systems in man that include coagulation of the blood and inflammation. Information is available on how arachidonate present in foods is converted to eicosanoids, and how these in turn can result in a variety of prostaglandins, which in different ways affect the aggregatory action on platelets (Walsh 1990 : 136; Duthie and Barlow 1992 : 25-26; Leaf and Weber 1988 : 550-551).

The research undertaken on fishermen and maritime communities and their families described here, in particular on the Greenland Eskimos and Japanese fishermen, confirms that a

diet containing fish can reduce the incidence of heart attacks. The information obtained in this research is applicable to other maritime communities that either use or used the sea as a primary source of food. The Bronze Age populations of Crete and the Aegean could be included amongst these. Ackman (pers. comm.) suggests that fish in the diet may have provided an extra few years of productive life for males that could have benefited the community. This advantage would have been lost in the Late Minoan period if fish consumption had been largely replaced by agricultural products.

#### PLATE

Cretan squid boat in Siteia harbour showing line for multiple hooks and lamp for night fishing



## 7. DEMOGRAPHIC EVIDENCE FOR THE DEVELOPMENT OF MINOAN CRETE

### 7.1 Agricultural development, settlement expansion and population growth in Minoan Crete

The agricultural potential of a region, growth in numbers of settlements and population increase are interrelated. Settlement expansion in Crete and Messenia in the Bronze Age, for example, has been demonstrated graphically by an approximately straight line (Renfrew 1972 : 233 Fig. 14.2). Renfrew attributes this linear growth to "a natural and uninhibited growth without severe constraints imposed, for instance, by very limited food supplies or other constraining factors" (*ibid* : 232). The potential of Crete to produce food is thus reflected in the number of Bronze Age settlements and estimates of their populations. The intention in this section is to compare the different models proposed for agricultural, settlement and population expansion on Minoan Crete with evidence obtained from excavations and intensive site surveys.

Many years ago Gordon Childe pointed out that a feature common to the growth of civilisation was that farmers were induced or compelled to wring a surplus from the soil above their own domestic requirements (1942 : 69). This surplus was then made available to support new economic classes not directly engaged in producing their own food. The rise of these new economic classes that made possible, for example, the emergence of a priestly class, enables a distinction to be made between self-sufficient rural family economies and the advent of proto-urban economies that depended on specialisation and exchange. The concept of an agricultural surplus, allied to improvements in agricultural techniques, appears in a number of models for Aegean prehistory that attempt to explain the rise of a Late Bronze Age palace economy (Renfrew 1972 : 38-44; Halstead 1981a : 187-213; Gamble 1981 : 215-229; Sherratt 1981 : 261-305; Van Andel and Runnels 1988 : 234-47).

The interrelationship between increased agricultural productivity and population growth poses a problem, however, since it is sometimes difficult to establish whether the increase in numbers was the cause or effect of advancements in agriculture (Boserup 1965 : 11).

Some twenty five years ago, Renfrew proposed his well-known model for a redistribution system of subsistence commodities that "emerged as a consequence of intensive exploitation of a

new spectrum of food plants, notably tree crops, yielding a new diversity in produce" (1972 : 480). Central to this model is the domestication of the vine and the olive by the third millennium BC which, together with cereals (wheat and barley), made up the so-called 'Mediterranean triad'.

While Runnels and Hansen question the early introduction of the olive (1986 : 299-308), Sarpaki (1990 : 70-75) suggests that the concept of a 'triad' may need revision since it ignores the agricultural and nutritional importance of the leguminous plants which were gathered and cultivated from the earliest times. These plants have wide economic value and restore nitrogen to depleted soils. Legumes have largely escaped attention because of their relative absence on archaeological sites but would have provided protein and calories when meat was in short supply.

Halstead (1992 : 107-117) and Gallant (1991 : 75-79) question Renfrew's concept of increased agricultural production through intensification (1972 : 490). Halstead argues that the archaeological evidence points to a more ecological model that emphasises diversification of crops and an irregular flow of goods to the palace centres. Evidence for wheat, barley, olives, the vine and legumes indicate diversification and may imply that the Aegean farmer was aware of the risky nature of his industry and ensured that if one crop failed there were others to fall back upon. Gallant's concerns are with the labour requirements and potential yields of the main Greek crops. He points out that on Melos, 48 man-days/hectare/year were spent cultivating wheat and 45 man-days/hectare/year were devoted to barley (Wagstaff and Augustson 1982 : 117, *cited* Gallant 1991 : 75).

For olives a calculated composite figure of 125 man-days/hectare/year is quoted (Davis 1973 : Appendix 6, *cited* Gallant 1991 : 75-76). Gallant suggests that an ancient Aegean farmer worked between 175 and 200 days per year. Certain factors could, however, have detracted from productivity. For example a lack of manpower within the farming unit would reduce the yield, particularly in the latter stages of its life-cycle; similarly the need to donate agricultural produce to additional workers would reduce any surplus produced. Celebrations and deaths within the community might require additional donations of food, further depleting food stocks.

Gallant argues that the average 4 to 6 hectare Greek farm would probably not achieve its crop potential for some two-thirds of the time. Since, however, the potential of any farm is predetermined by the fertility of the soil, available water and access to markets, criticism of this

nature is difficult to substantiate. The vulnerability of manpower and the cyclical pattern of crops do, however, emphasise the precarious nature of the farming in the Aegean and the need to diversify.

Halstead's model (1981a : 197-213) has as its basis a redistribution system for agricultural produce centred on a concept of 'social storage'. It is argued that communities from the Late Neolithic/Early Bronze Age produced a greater diversity of agricultural goods, the surplus of which was stored for exchange with nearby villages as the need arose. This system buffered periodic fluctuations and crop failures.

Gamble (1981 : 215-29) offers a third model for development in the Aegean agricultural economy that highlights the possible controlling mechanisms of the Mediterranean Bronze Age redistribution system. He suggests that olives, wheat and products of the vine were not redistributed because of their common availability in the Aegean. A form of social control emerged, however, through the medium of agricultural production which saw certain areas being permitted to produce a surplus of products. In this model small dispersed units maintained alliances through exchange over extensive areas. To meet Middle Bronze Age demands intensification and specialisation occurred.

Sherratt (1981 : 261-305) offers another model that attributes advancement of agriculture in the Bronze Age to a 'secondary products revolution'. This theory involves interaction between plant and animal domesticates and the use of animal power for ploughing and transportation. Secondary products such as hides, wool and fermented milk products offered better opportunities for trade. Sherratt suggests that cereal farming in particular "allowed a massive increase in population, first in village communities and later in towns and cities" (*ibid* : 261).

Yet another model owing much to Halstead's concept of social storage (1981 : 187-213) and Sherratt's theory of a secondary products revolution but emphasising trade, technology and geography, is offered by Van Andel and Runnels (1988 : 234-47). Pointing out that the Neolithic/Bronze Age transition in the Aegean was more complex than previously envisaged, the authors suggest that an Aegean trade network existed as early as the Fourth millennium BC probably linking Anatolia, Crete, Rhodes, Attica and the Peloponnese. Van Andel and Runnels argue that the concept of social storage works if viewed as part of a trade system. Furthermore,

they emphasise the interplay between trade and power. Goods transported from Aegean coastal centres could have included clay, salt, domesticated plants and animals, wool, honey, hides, cheese, textiles and dried or salted fish. The bulk of these products would have left few archaeological traces.

Because all these proposed models involve aspects of the agricultural economy Hansen (1988 : 39-52) suggests that criteria such as crop diversity, crop purity, specialisation, climatic fluctuation and technical innovation should be testable by analysing archaeobotanical remains. Scanty plant remains from Greece, Crete and the Aegean islands, however, offer only limited support (*ibid* : 42-3, Table I). The plant residues generally show little diversity with many of the same species being exploited from the early Neolithic period to the Bronze Age. Palaeobotanical evidence does suggest, however, that two new species of legumes were cultivated and that the quantity of grape and olive remains increase in the Late Neolithic and Early Bronze Age (*ibid* : 48). Though the number of grape seeds show an increase at various archaeological sites, evidence for olive cultivation, as discussed earlier, is less certain. Foxhall, however, queries the paucity of evidence for olives in the Early Bronze Age, pointing out that in processing olives the pips would be crushed in the stone presses and never recovered archaeologically (Sarpaki 1990 : 75, see Discussion).

Emmer (*Triticum dicoccum*) is the most common domesticated cereal throughout the Bronze age in southern Greece (Hansen 1988 : 41). Grains attributed to bread wheat (*T. aestivum*) occur in the Early Neolithic levels at Knossos (Evans 1968 : 241-264), again as a fairly pure deposit in the Late Minoan II period (Hansen 1988 : 42). Bread wheat is a demanding crop in terms of moisture and soil fertility, and Hansen suggests that it is possible that conditions in Greece during most of the Neolithic and Bronze Age were unsuitable and suggests that its reappearance in the Late Bronze Age may indicate that agricultural techniques such as crop rotation had developed to the extent that bread wheat could be grown on a limited scale (*ibid* : 43). The recovery of seven storage containers at Assiros in northern Greece containing einkorn, emmer, spelt, broomcorn millet, barley and bitter vetch could point to the production of an agricultural surplus. The containers held some 4000 to 5000 litres of produce which the excavators suggest was enough to feed 20 people for a year (Jones *et al* 1986 : 96-103). Hansen notes that, in this instance, the produce was probably communal property forming the basis for a small redistribution centre (1988: 50). Overall though, because of the scanty nature of

archaeobotanical evidence, the only aspect of Early Bronze agriculture relating to the models and supported by botanical evidence is that of crop diversity for southern Greece.

Sarpaki (1992 : 61-73) emphasises the importance of climatic, edaphic and geomorphological constraints in Greek agriculture, pointing out that these would have been decisive factors in the kind of adoption or innovation as envisaged in the models for the Neolithic/Bronze Age transition. She suggests that the soils of the Aegean, and Crete in particular, are generally poor since the arid summers draw up stored water containing nutrients to the surface by capillary action. These nutrients are concentrated at the surface and are not available to the crops without some kind of water transfer. Nitrogen is in short supply in Greek soils since their aridity prevents the action of micro-organisms that help to produce good soil texture, aeration and nutrient retention. Intensification of agriculture in the Bronze Age, as set out in some of the models discussed, must have brought about a deterioration of the soil with the consequence of reducing the yield. Legumes would have been of primary importance in perpetuating an intensive agricultural system, since they would have assisted in keeping the soils fertile and receptive to future crops.

Redistribution of agricultural products, social storage, a secondary products revolution, trade and innovation relating to metallurgy and ceramics, are recurring themes offered as explanations for the Neolithic/Bronze Age transition and the rise of the economies that supported the palace centres in the Aegean. Scholars are unanimous, however, that more evidence is needed to confirm the theoretical reconstructions for economic changes in Greek farming practices, increase in settlement numbers and alterations in demographic patterns. Fortunately some of this evidence is forthcoming from more intensive archaeological surveys that have been undertaken in recent years on Crete and the Greek mainland.

In order to obtain quantitative data on settlement increase and population densities archaeologists rely mainly on field surveys. The relationship of the site area to population provides some check on the reliability of the final figures, bearing in mind, however, that prehistoric population levels were low in comparison to modern demographic patterns. The data obtained by archaeological site surveys reflects the thoroughness and scope of the field-work. In addition to the desirability of modern intensive survey techniques, there is the problem of identifying correctly the remains of the actual settlements. Renfrew's earlier work in the Cyclades

(1972 : 249-250) highlights some of the problems. If cemeteries are included in his survey there are 127 Early Bronze Age sites. Of these only 50 were positively identified as actual settlements. Because each community theoretically had a cemetery, Renfrew multiplied the positively identified sites by 3. A factor of 2,5 was applied for the Middle Bronze Age and 2 for the Late Bronze Age sites. Because of the potential for errors in conducting site surveys, various scholars have commented on the criteria and procedures. These include Renfrew himself (1972), McDonald and Hope Simpson (1972), Blackman and Branigan (1975, 1977), Renfrew and Wagstaff (1982), Cherry (1982, 1990), Sanders (1984), Jameson, Runnels and Van Andel (1994) and Dickinson (1994). Recent publications show progression to more controlled regional surveys, that take cognisance of factors such as the agricultural potential of the land, the different regional settlement patterns and trends to nucleation of the population. Attention is also directed to associations between settlements, cemeteries and geographical features that may, for example, assume ritual significance such as the peak sanctuaries.

Cherry (1982 : 14-15) and Jameson *et al* (1994 : 214-50) discuss procedures for carrying out archaeological surveys. Traditional methods used in the Aegean are divided into three types: exploratory travels, extensive reconnaissance or intensive surveys. Exploratory travels cover the kind of field work undertaken in the Aegean in earlier years, reliance being placed on informants or a knowledge of local conditions. 'Travels in Crete' (Pendlebury, Eccles and Money-Coutts 1934 : 80-100) and 'Travels in Crete, 1962' (Hood, Warren and Cadogan 1964 : 50-99) are examples of this method of collecting archaeological site information. The intention was to locate archaeological sites over as wide an area as possible.

McDonald and Hope Simpson's survey of Messenia (1972 : 117-147) and Renfrew's work in the Cyclades, fall into the category of extensive reconnaissance. Informants, aerial survey photographs, ancient sources, economics and locations are considered. Cherry (1982 : 12) suggests that this type of survey has a bias towards the major nodes of settlement, communications and administrative activity.

More recently intensive surveys covering closely defined areas of study have been introduced in an attempt to address some of the problems present in the two previous methods. Blackman and Branigan's survey of the Ayiofarango valley on the south central coast of Crete (1975 : 17-36; 1977 : 18-34) and Wagstaff and Cherry's study of settlement and population on

Melos (1982a : 136-155) are earlier examples of intensive surveys. Recent examples include the Argolid exploration project (Jameson, Runnels and Van Andel 1994 : 214-259), the Vrokastro Project (Hayden, Moody and Rackham 1992 : 293-353), the survey of Kavousi, east Crete (Haggis 1996 : 373-432), excavations at Pseira (Betancourt and Davaras 1988 : 207-225) and the Ziros project directed by Keith Branigan, an intensive field survey around the villages of Lamnoni and Katellonas in east Crete.

Other regional surveys include that of Peatfield and Morris in the valley around Atsipadhes (*cf.* 1994-95 : 25) and Watrous and Blitzer at Gournia (1995 : 313). Watrous in addition refers to surveys that have been carried out or are in progress (1994 : 698). Those listed include the Akrotiri peninsula of Chania, Sphakia, Knossos, Kommos, Siteia and Zakro.

Discussion on site surveys will generally be restricted to those which provide information on the environmental background and agricultural potential of the area together with the details of settlement patterns and possible population estimates. Modern archaeological surveys enable comments to be made on relationships between the number and distribution of settlements, tholos tombs, peak sanctuaries (Bintliff 1977 : 632) and the theoretical population an area might have supported. Estimation of population densities is difficult and some of the problems have been discussed by *inter alios*, Renfrew (1972: 249-254), Hassan (1981 : 1-6), Jacobsen (1981 : 313), Cherry (1982 : 136) and Dickinson (1994 : 54). The kind of error that can occur in estimating populations was highlighted by Sanders (1984 : 254, Table 4), who showed mathematically that figures for the amount of land needed to support an estimated Bronze Age population at Phylakopi on Melos are incorrect (Wagstaff, Augustson and Gamble 1982 : 177, Table 14.5).

On Crete, land areas settled in the Neolithic and Bronze Ages were primarily determined by environmental factors such as the geomorphology of the island, the soil types, available water and accessibility to other parts of the island (Pendlebury 1939 : 3-16; Hood 1971 : 15-19; Dickinson 1994 : 23-29). Crete is divided by a single mountain chain that runs the length of the island. On the south side it extends down to the sea and the settlements are approached by gorges that split the mountain chain. To the north, spurs divide up the more habitable land and to the west broken country descends to the coast. East of Mount Ida the country is low and rolling and to the south is the Plain of Mesara, one of the most fertile, well-watered and productive parts of Crete. An analysis of settlement patterns on Crete showed that where all primary determinants

(water, soil and geomorphology) were satisfactory, occupation of the land generally extended through all three Minoan periods (Riley 1974, Section 5).

An unusual feature of the settlement pattern on Crete is the number of upland plains, the higher of which are traditionally used for summer grazing. Others such as the plain of Lasithi were well-populated in the Bronze age. On the Siteia peninsula there are numerous smaller plains in the mountains many of which are situated low enough to allow year round occupation

Information gathered from archaeological surveys in Crete, Greece and the Cyclades suggests that population densities of northern and southern Greece differed quantitatively in the Neolithic and the later Bronze Age. In Thessaly and Macedonia for example, finds of characteristic tell mounds indicate that the northern Neolithic was both prosperous and of relatively long duration. Only on Crete in southern Greece is the occupation deposit at Knossos comparable to a Near Eastern tell. For the later Minoan and Mycenaean periods the number of sites located in southern Greece exceeds that in the north, suggesting that southern Greece, Crete and the Aegean islands were more densely populated. The pre-eminence of southern Greece is confirmed by a table of archaeological sites published by Renfrew (1972 : 231-32, Table 14 III).

More recent intensive surveys strongly emphasise the relationship between population density, geomorphology, agricultural potential and the growth of settlements. The survey of the lower Ayiofarango valley, southern Crete (Blackman and Branigan 1975 : 17-36; 1977 : 18-34) indicates that the population of the area was probably limited by the availability of water which, though plentiful in the winter, was reduced to only two sources by the end of summer. Other limitations to agriculture and settlement were the poor soil, summer aridity and the frequent years of low rainfall, factors noted by Sarpaki (1992 : 61-62) and referred to earlier.

Archaeological evidence points to three main occupation periods in the Ayiofarango Valley separated by intervals when the valley was effectively abandoned, apart from occasional visits by shepherds and individuals collecting figs and olives. Occupation in the sub-Neolithic/Early Minoan period suggests that the earliest inhabitants were farmers rather than pastoralists, with population growth progressive rather than prolific.

Though limited prosperity is evident by Early Minoan II and certain sites show continuity into the Middle Minoan period, other evidence points to a decline in population between Middle Minoan I and Late Minoan I. The decrease in population is associated with disuse of the tholos tombs of the clans or extended families. Blackman and Branigan (1977 : 69) interpret the evidence as indicative of a possible population movement to the coastal centres where redistribution of produce and increased trade was taking place.

The archaeological survey of the Ayiofarango valley demonstrates that the settlement pattern was largely determined by agricultural considerations with the Early Minoan sites situated on the best land. Bintliff calculates that about 225 hectares of arable land was needed to sustain the population of the valley (1977b : 29-30). On a holding of some 6 hectares, he estimated the lower Ayiofarango areas could have supported 34 families. Poor soil and lack of water, however, might have reduced this to 17 thus giving a theoretical population of 102-140 persons in the valley. Blackman and Branigan favour a slightly higher density: 120-145 persons, based on evidence from tholos tombs and farmsteads (1977 : 71).

The survey at Kavousi covered 21 square kilometres, the area extending from the western ridge of the Siteia mountains to the eastern edge of the Bay of Mirabello and the coastal plain (Gesell, Preston Day and Coulson 1988 : 279-301; Haggis 1996 : 373-432).

Preliminary results of the survey show a rise and fall in population levels in the Early and Middle Minoan periods somewhat similar to that seen in the Ayiofarango survey although the patterns are not contemporaneous. At Kavousi, population numbers increased in the Early Minoan/Middle Minoan I-II periods, while decreasing in Middle Minoan II/Late Minoan I. This loss of population could possibly be associated with a movement to coastal centres as suggested by Branigan and Blackman (1977 : 69) for the Ayiofarango valley.

Nine Early Minoan I-III habitation sites were located, these being nucleated, near the sea, on good arable land and with an adequate water supply. In the Middle Minoan period the distribution shifts from an Early Minoan village to the Middle Minoan cluster of farmsteads, the number of sites increasing to 53, the population probably reaching maximum in Middle Minoan II. Haggis suggests that the reasons for this settlement expansion are unknown and probably lie outside Kavousi. By Middle Minoan III/Late Minoan IB the settlement pattern changes with four

settlements abandoned and four probably abandoned. Changes in the economy are suggested by the replacement of a farmstead by a larger rural house. The archaeological evidence indicates a striking reduction in settlement numbers in Late Minoan II-III, with near abandonment of the Kavousi area.

Kavousi was a peripheral area and as such it may provide a localised assessment of economic changes relative to bigger centres. In east Crete, however, the functions of larger centres of population such as Gournia and Kato Zakro remain unclear, as does their relationship with Knossos. A figure of 600-1200 persons is suggested for the area of the Kavousi survey. Spread over the 21 square kilometres this would give a population density of 28-56 persons per square kilometre.

The survey of the Vrokastro area, also in East Crete (Hayden, Moody and Rackham 1992 : 293-353) was intended to "place settlement within a regional context in order to better understand how it functioned and related to the environment". This intensive survey was carried out by dividing the area into thirteen zones. These zones were further subdivided into units, the units being further subdivided into transects that were then surveyed by field-walking.

Three Neolithic sites were positively identified in the Vrokastro survey with a further three possible sites. A few Final Neolithic sherds mixed with Early Minoan I and later material suggested that coastal sites were possibly favoured for settlement. The Early Minoan/Middle Minoan sites were principally situated on hilltops and slopes, a cluster of Early Minoan/Middle Minoan sites in the fertile Istron river delta again suggesting early settlement. Between Early Minoan III and Late Minoan I settlement expanded in four areas: the Istron valley, the Xeropotamos basin, the Aphenidi Christos valley and the upland area south of Vrokastro. Though never a major Bronze Age centre on an island-wide scale, activity in the area gradually increased throughout the period culminating in Late Minoan I. During Late Minoan III the absolute number of sites decreased and nucleation of settlement began.

Watrous describes his survey of Lasithi (1982) as "a history of settlement on a highland plain in Crete". Geographically well-defined, Lasithi is reported to be the only area of Crete above 800 metres that is permanently settled all year round. The report combines results from surface survey, excavated material, historical documents and local tradition. The archaeological

evidence indicates that the tops of the hills near the edge of the plain were occupied in Early Minoan I to III, the economy combining crops, pastoralism and hunting. Settlement increased in the Middle Minoan period reaching a peak in Middle Minoan III. By Late Minoan I some of the smaller and higher sites were deserted, this loss of population being attributed to a movement of people down to the edge of the plain. By late Minoan III the population had dropped sharply, although the complex of houses at Plati around a central court is evidence of some recovery. This complex, it is suggested, may relate to a Mycenaean population living amongst the remnants of the earlier Minoan inhabitants.

In his review of the Lasithi report, Hope Simpson (1983 : 404-405), accepts that the evidence is successfully interrelated, but suggests that a more environmentally based approach would have been useful, a full investigation of the fauna and flora especially so. Measurements of the terraces on the foothills would also provide a more reliable estimate of land use potential, particularly when the plain itself was not cultivated. Lasithi however, from the survey evidence, follows a pattern of settlement and population expansion in the Early Middle Minoan period with marked decline in the Late Minoan period.

The island of Mochlos is archaeologically important since it has substantial remains of a Minoan settlement and cemetery. The island and adjacent coast have a history of archaeological exploration stretching back some ninety years (Seager 1909 : 273-303). Twenty-five sites represent the Bronze Age from Early Minoan I to Late Minoan III C. The present survey and excavation are intended to provide an outline of occupation in the area over 4000 years (Soles and Davaras 1992 : 413-445). Another aim is to establish a relationship between settlement on the island and sites on the adjacent plain. Recovery of botanical, faunal, marine, and human skeletal material is given priority. The geology and nature of the land at different periods of coastline changes is also studied.

It is unclear when the first settlers arrived in Mochlos. If occupation occurred in the Final Neolithic, it was small and short-lived, settlement effectively beginning in Early Minoan I. By Early Minoan II/III the town was a flourishing centre for trade and a potential port for goods from the Near East. The settlement is estimated at 0,8 hectares, archaeological remains suggesting that it extended along the south coast of the island for some 125 metres. Population is estimated at 220-330 individuals calculated on 55 houses (Whitelaw 1983 : 338-339). Lower

figures of 150-220 are obtained if calculations are based on 30 family burial tombs. A decline of burials in Middle Minoan IA indicates a loss in population although the settlement was not abandoned.

Survey and excavation indicate seven periods of occupation in Mochlos, with two further sites identified for excavation on the adjacent coastal plain. Study of these and the environmental background of the coastal plain may provide information on the relationship between the coastal and island settlements.

Excavation of a Middle Minoan I/II cemetery at Kalo Khorio, east Crete, revealed the remains of an Early Minoan I building consisting of three rooms. Situated 7 kilometres from Gournia the settlement provides data on the stratigraphic transition from Early Minoan I to Early Minoan IIA, as well as limited information on settlement, agriculture and trade (Haggis 1995 : 313; 1996 : 645-681). Located in the area of Istron, the coastal community of the upland village of Kalo Khorio, the building represents the only extant domestic architectural remains of certain Early Minoan I date in east Crete and parallels Debla in west Crete (Warren and Tzedhakis 1974 : 299-342). Sited on the coastal plain and foothills of Kopranes, the settlement utilised the agricultural potential of the area. Faunal material recovered reveals that the inhabitants exploited the grazing to advantage. Similarly marine debris points to the use of the marine resource, the settlement being 0,5 km from the sea.

Contact with the wider Aegean is suggested by finds of obsidian and a copper blade. The absence of Cycladic imports, particularly pottery could indicate a phase of Early Minoan I that preceded economic connections between Crete and the Cyclades as seen at Ayia Photia (Davaras 1971 : 392-397; Watrous 1994 : 701-704).

The absence of an Early Minoan IIA level highlights a gap between the abandonment of the building and the construction of the cemetery in Early Minoan III/Middle Minoan I. Haggis suggests that this break in occupation might 'coincide with a population increase, a growth of settlement size and numbers, the founding of new sites such as that at Myrtos and Ayia Photia, Ierapetra, and an increase in interregional trade and overseas contacts' (1996 : 681). The surveys of the Ayiofarango valley (Blackman and Branigan 1977 : 67-68) and the Mesara (Watrous 1982 : 10-11) may support this theory, since they both reveal an increase and dispersal of Early Minoan

I settlements often as hamlets and located on the coast or inland. Unfortunately deep alluvial deposits on the slopes of the Koprane hill together with modern building operations preclude a survey to establish the extent of Early Minoan occupation of the area.

Pseira is a small rugged island 2 km long situated at the end of the Bay of Mirabello. Composed mostly of steep hillsides and cliffs, it has a good harbour and several small coves located on the south eastern coast. This island is the site of a Minoan town of about sixty to seventy houses first excavated in 1906-1907 (Seager 1910). The present Pseira project combines a survey of the island, a study of soils, botanical remains and land use as well as cleaning and further excavation of the settlement (Betancourt and Davaras 1988 : 207-225; Hope Simpson and Betancourt 1990 : 320-323; Floyd, Onyshkevych, Beaudoin and Mitrakis 1995 : 313). Occupation of the settlement extended from the Final neolithic to Late Minoan I when it reached its maximum size and greatest population.

Sometime in Late Minoan I the settlement was destroyed followed by a small reoccupation in Late Minoan IIIA2, after which the island was mostly uninhabited. The accessible sheltered harbour suggests that trade and fishing were important to the economy of the settlement.

The isolation of Pseira made it possible to identify agricultural terraces that have not been used since Minoan times. These terraces, probably used mainly for olive and vine cultivation, cover most of the accessible parts of the island and demonstrate intensive use of the available land. The stone built terraces were in some cases only large enough to support a single olive tree or a few vines. Pottery associated with the terraces indicate limited use in the Early Minoan period with progressively greater use in the Middle and Late Minoan I periods. These phases generally coincide with the expansion of the settlement and population growth (Betancourt and Hope Simpson 1992 : 47-54). Two large dams were built in Late Minoan I on the slopes above the Minoan town, the best preserved holding between 500 and 600 cubic metres of water. As the terraces are above the dams, water for the crops would have to have been carried uphill in clay containers. A change in soil colour between the Middle and Late Minoan I levels in terrace b2 may be the silt transported from the dams as a form of soil renewal.

Betancourt and Hope Simpson divide the use of the agricultural land on Pseira into three periods, the first from the Final Neolithic until the Middle Bronze Age, characterised by slowly increasing use of the available land. Tillage was deep and manuring a possibility. The second phase dates to late Minoan I when further terraces and the dams were built. The third and final period was in Late Minoan III when Pseira was briefly re-inhabited after the period of abandonment. Only a single house of this occupation has been located and the population was apparently small. Today no soil remains behind some of the largest terraces and most of the smaller terraces are in poor condition suggesting that in Minoan times they would have needed maintenance on a regular basis.

Any attempt to arrive at population numbers for Pseira in the Middle Minoan/Late Minoan period is speculative. On the basis of sixty houses and a family of five to each house, some 300 people could have occupied the settlement. This would have represented a fairly high density for the Bronze Age requiring a substantial economic and agricultural base to support it.

A preliminary report on the intensive archaeological survey of the Gournia area records the location of 155 new sites over some 21 square kilometres (Watrous and Blitzer 1995 : 313). Occupation of the Gournia area began in the Final Neolithic/Early Minoan period with settlement and population expansion in Early Minoan II. After this the settlement was much reduced. Survey of the northern Isthmus of Ierapetra and the Gournia area suggests that the countryside was largely deserted during Early Minoan III (Watrous 1994 : 718). Other surveys, for example that of the western Mesara (Watrous 1982 : 68) point to a similar lack of evidence for settlement in Early Minoan III/Middle Minoan IA. Little Middle Minoan I A material was similarly found in the Ayiofarango valley in southern Crete (Blackman and Branigan 1977 : 68). At Gournia, re-settlement of the countryside only began again in Middle Minoan IA, increasing once more in Middle Minoan IB/Middle Minoan II. Settlement fell slightly in Middle Minoan III and sharply in Late Minoan III A-B.

While recent archaeological surveys focus on the natural environment and history of settlement in the area of Gournia, Soles has attempted to clarify the evidence for the earlier town that immediately preceded the Neo-palatial settlement on the Gournia ridge (1979 : 149-167). The land around Gournia was attractive for settlement since it was fertile, well-watered and had access both to the sea and a primary overland route. In addition to springs that rise in the hills to

the south, the Gournia river lies to the west of the town. Land on either side of the settlement was suitable for cultivation and grazing. Topographically, the hill provided land for settlement spatially limited by its own configuration, this characteristic appearing to play a part in the choice of new settlements in east Crete (*ibid* : 150). Apart from potential for agriculture and pastoralism, the location of the town offered opportunities for fishing and trade.

Although the earliest archaeological evidence belongs to the end of the Neolithic, evidence suggests that a new group of settlers arrived in Early Minoan II (*ibid* : 150). Dickinson suggests that the town-like character of this early Gournia foreshadowed that of the later town (1994 : 60). The foundation of Gournia coincided with the arrival of other settlers in east Crete and the establishment of further settlements. These included Mallia, Palaikastro, Priniatikos Pyrgos, Vasiliki, Myrtos and Zakro (Warren 1972 : 272), also Pseira (Betancourt and Davaras 1988 : 210).

Contrary to evidence for a decline in settlement in the Gournia area at the end of Early Minoan II, occupation of the town persisted. Burials continued at Sphoungaras and construction of both domestic buildings and tombs at the beginning of the Middle Minoan I point to the development of urbanisation. Coincidental with the expansion of Gournia, other early Cretan settlement with closed plans expanded into more open towns, surfaced streets and individual houses becoming evident (Branigan 1972 : 752-753).

The construction of built tombs on the north spur of the Gournia ridge point to a more socially and economically complex community, the tombs suggesting an accumulation of wealth in the hands of some ten families (Soles 1979 : 167). Any attempt to place these families in context of the town's population would be speculative.

The survey of the western Mesara plain is an extensive joint American/Greek project, the scope of which covers the history of settlement from the Neolithic to the present day (Watrous *et al* 1993 : 191-248). The methods used can be traced back to the interdisciplinary Minnesota Messenia Expedition (McDonald and Rapp 1972), the survey team comprising archaeologists, geologists, botanists, historians and ethnographers. The intention is to document how environmental factors through time affected the development of a complex society in the region.

The Mesara is the largest plain on Crete (362 square kilometres) and is located in the south central part of the island. The western Mesara is drained down to its centre by the Ieropotamos River which flows westward into the Libyan Sea. More than two thirds of the best arable soil (40485 hectares) on the entire island is located in the Mesara. Watrous *et al* (1993 : 194) point out that throughout the history of Crete, the western end of the Mesara has been densely populated because of its rich alluvial bottom land, ample water and open coastline. Agriculturally the lowland comprises orchards, grazing and garden plots while the hills and valleys south of Phaistos are planted with grain, legumes and olives.

The following preliminary conclusions on site and settlement patterns were reached based on three survey seasons:

Over 100 new archaeological sites were located, the earliest dating to the Final Neolithic of which eight were identified. These were situated on low hills near the coast on the floor of the plain, in caves and especially on slopes and ridges near the edge of the plain. All, with one exception, were under soil and the authors suggest that the Final Neolithic sites could be under-represented. The total number of Early Minoan I sites located was almost double that of the Final Neolithic (*ibid* : 223)

Small settlements, hamlets or farmsteads were identified in the countryside, these being again located on ridges and slopes, widely dispersed near water and arable land. Extensive land clearing for agriculture probably produced the nascent Early Minoan erosional sequence that the modern situation suggests (*ibid* : 224).

During the Early Minoan period Phaistos was the largest settlement with an estimated population of 300-450 persons (Whitelaw 1983 : 339).

Few Early Minoan III/Middle Minoan IA sites were located suggesting that many of the smaller sites were abandoned at the end of Early Minoan II.

In the succeeding Middle Minoan IB - II period, settlement and population in the western Mesara reached a peak, the sites varying greatly in size, some newly settled and others showing earlier occupation. Phaistos extended to some 1500 x 1000 metres and was the administrative

centre of the region as evidenced by the architecture of the first palace, ceremonial courts and storage for redistribution of goods.

Most sites show continued occupation in Middle Minoan III/Late Minoan I, although the overall number of sites appears less. This could indicate a decline in population or a move to larger centres. The survey indicates that the people of the Mesara experienced continuity and growth in the Late Minoan III A2 - B period. The authors point out, however, that the survey data was obtained outside the population centres and reflects rural communities that tended to change slowly.

By Late Minoan IIIC the countryside was nearly abandoned, few sites of this period being found by the survey team.

Finally brief mention must be made of the archaeological survey carried out at Palaikastro prior to re-commencing the excavation of the Minoan town (MacGillivray and Sackett 1984 : 128-159). Palaikastro in eastern Crete is a well-planned town with buildings of superior quality. The history of the settlement spans from Early Minoan I to Late Minoan IIIC, the town being located on a raised ridge on the lower slopes of Petsophas. Wealth and sophistication are evidenced by the quality of the finds and the paved streets.

The purpose of the survey was to establish with greater accuracy the extent of the settlement which was first excavated in the early part of the 20th Century by Bosanquet (1902 : 286-316). The survey revealed that the town was more extensive than previously thought, the town centre comprising not only the presently excavated portion but also occupying an area of low ground sloping to the sea. This area is seen as part of urban expansion in Middle Minoan III/Late Minoan I which was characterised by a ribbon development along the coast, up the inland ridges and around a cemetery to a beach that was probably the harbour (*ibid* : 140).

The models proposed by Renfrew (1972 : 38-44), Halstead (1981a : 187-213), Gamble (1981 : 214-229), Sherratt (1981 : 261-305) and Van Andel & Runnels (1988 : 234-305) to explain the rise of the Minoan economy all involve aspects of agriculture. The models highlight different concepts such as the 'secondary products revolution', the need to accumulate an

agricultural surplus and a means of redistributing produce - factors that should be reflected in different degrees in the surveys reviewed.

The surveys reveal that the choice of a site for occupation in the Early Minoan period (or the Final Neolithic) was not haphazard but was determined primarily by agricultural considerations. These would include the availability of water and the proximity of arable and grazing land. Sherratt (1981 : 291) writes that "early agricultural systems were characterised by a highly selective pattern of land use in which population was concentrated in a few zones of high productivity, and relatively small areas of land were intensively cultivated". The surveys undertaken in Crete demonstrated that coastal plains, hill tops and slopes and areas of rich alluvial soils were chosen for settlement. In the case of the west Mesara Plain (Watrous *et al* 1993 : 194), the rich alluvial bottom land, ample water and an open coastline offered excellent opportunities for agricultural settlement. At Gournia, not only was water plentiful but adequate land was available for cultivation and grazing (Soles 1979 : 150). On the offshore islands of Pseira and Mochlos, the presence of natural harbours and opportunities for trade took precedence over agriculture. On Pseira, however, food production was not neglected since terracing was used increasingly from Early Minoan I, together with agricultural dams constructed in the Late Minoan period (Betancourt and Hope Simpson 1992 : 47-54).

This relationship between water resources, settlement growth and population increase is highlighted in the survey of the lower Ayiofarango valley. A shortage of water at the end of summer and the frequency of unfavourable rainfall patterns led the authors to suggest that summer aridity may have reduced the estimated population numbers (Blackman and Branigan 1977 : 30).

In the majority of areas surveyed occupation began either in the Final Neolithic, Early Minoan I or II. Early Minoan I is seen as "the period *par excellence* of settlement expansion in Bronze Age Crete" (Watrous 1994 : 701). The number of Early Minoan I sites identified in the western Mesara, for example, were double that of the Final Neolithic (*ibid* : 701). To the south in the Ayiofarango valley the number of sites increased from two in the Final Neolithic to at least eleven in Early Minoan I (Blackman and Branigan 1977 : 67-68). Associated with this increase in site numbers is a transition from farmsteads or seasonal camps to hamlet sized settlements. It is suggested that there were probably only a few sites with populations of several hundred; much

commoner were small villages of less than ten households or even single farmsteads (Dickinson 1994 : 54-55).

Of the different models proposed for the development of pre-palatial Minoan agriculture perhaps the most relevant is that of the 'secondary products revolution' (Sherratt 1981 : 261-305). While the domestication of plants and animals allowed a substantial increase in the Middle and Late Neolithic populations, interaction with plant and animal domesticates gave rise, from the Final Neolithic, to a range of secondary commodities that could be stored, exchanged or traded such as wool, hides, textiles and fermented milk products. This period probably also saw the beginning of the use of animals for transport and traction. Probable changes also took place in the social structure of family units. While males were occupied herding animals or ploughing, the women were involved with the tasks relating to the production of textiles - spinning and weaving.

It is suggested that on Crete it may be possible to identify two phases in the introduction of new technologies and the exploitation of hitherto uncultivated land which encouraged an increase in settlement numbers (Watrous 1994 : 704). Whereas the first phase saw a greatly increased focus on pastoralism with some agricultural changes, the second saw a balance achieved between herding and fully developed agriculture.

Some idea of farming practice in Early Minoan I is obtained from the excavation of the three roomed farmstead at Kalo Khorio-Istron (Haggis 1996 : 645-681). Situated on the foothills of the coastal plain overlooking the Bay of Mirabello, the choice of site made good use of the agricultural potential of the land. Faunal remains, as yet unpublished, indicate that pastoralism formed part of the farming activities. Finds of obsidian and a copper blade point to contacts with the wider Aegean or internal trade. The later construction of an Early Minoan III/Middle Minoan I cemetery suggests that, after a break when the Early Minoan farmstead was abandoned, the area was re-occupied with an increase in population.

A more detailed picture of agriculture in Early Minoan I is provided by the excavation at Debla in western Crete (Warren and Tzedhakis 1974 : 299-342). The total area of the settlement, situated on a ridge, was about 900 square metres, a relatively small site. Water was scarce, with drinking water today being only obtainable at Kambia some ten minutes walk away

which was the probable source for the settlement. The soil is red earth originating from erosion and decomposition of limestone. Because of erosion the nature of the cultivable surface soil in Minoan times is uncertain.

Two free-standing single-roomed Early Minoan I houses with portions of at least one other were excavated. The recovery of faunal, botanical and other remains associated with agriculture point to a small community undertaking mixed farming probably comparable to that at Kalo Khorio-Istron. The recovery of clay spindle whorls at Debla indicates wool production as early as this period. Supporting this evidence are eighty fragmentary bones, predominantly goat, but including one fairly certain sheep. The age range of the animals, between 2 and 5 years, suggests summer herding.

The assemblage of plant remains identified from impressions in the coarse fabric of clay tubs offers a qualitative glimpse of the mixed cereal economy of the time. *Triticum dicoccum* (emmer wheat) was identified from several impressions and a few others were ascribed to *Hordeum* sp. (barley) and *Avena* sp. (oats). A carbonised grain as well as impressions were identified as *Bromus* sp. (brome) which is a grass which occurs as a weed in cornfields and is harvested and consumed with the main crop. While emmer wheat and barley are not unexpected, the presence of oats is unusual. Olive stones were recovered but not in pure Early Minoan levels.

Reconstruction of the economy of Debla suggests a small farming community, possibly an extended family, herding animals but with some sheep and cultivating a range of cereals and conforming broadly to Sherratt's model. Watrous comments that "the appearance of Early Minoan I sites, such as Debla, where the inhabitants grew and processed emmer wheat, barley and oats and kept herds of goats/sheep mainly for their secondary products (milk/cheese, wool and hides) is an archaeological manifestation of this new subsistence strategy" (1994 : 704).

Further evidence of this strategy is documented in the excavation report on the Early Minoan II settlement at Myrtos (Warren 1972). Established in Early Minoan IIA on a steep hillside overlooking the sea, Myrtos consisted of a single unit of about 100 small rooms. Warren estimates the population at 100 to 200 persons, based on the accommodation and site area of 1250 square metres (*ibid* 267). More recently Myrtos has been re-interpreted as consisting of five or six households and a maximum of 25 to 30 individuals (Whitelaw 1983 : 323-346).

The plateau just below the settlement was possibly used for cultivating crops but any soil retaining slopes and terraces would have been suitable. The hilly terrain would not have supported many cattle, but would have been suitable for goats or sheep. Myrtos today is arid and water is scarce. In the past water may have been obtained from springs or from the valley to the east or west.

The community at Myrtos practised mixed farming, archaeological evidence indicating the utilisation of a wider range of secondary products than at Debla. Barley and wheat were grown although nothing is known of the quantities. Vines were cultivated and the remains of grapes recovered could indicate wine-making. The evidence for olive cultivation at Myrtos and its wider implications for olive cultivation on Crete in the Early Minoan period were referred to earlier. Sheep, goats, pigs and cattle were kept, caprines greatly outnumbering all the other species. Analysis of the animal bones suggests that the caprines were bred as much for their wool as their meat. Finds of spindle whorls and loom weights, also rubbers of serpentine that may have been used for rubbing wool, provide further evidence of textile production. Pottery making and olive oil production were other secondary industries undertaken at Myrtos.

Pastoralism and agriculture at Myrtos is complemented by evidence from Trypeti an Early Minoan II settlement on the south coast (Watrous 1994 : 707). Here carbonised wheat, barley, peas, vetch and figs were recovered, the presence of legumes being noteworthy. Cattle, sheep/goat and pig bones were also recovered.

Evidence from Kalo Khorio, Debla, Myrtos and Trypeti for mixed agricultural economies suggest that in the Early Minoan period these small farming communities were progressively moving from a purely subsistence type economy, to one that encompasses a expanding range of secondary products. The fortuitous preservation and chance recovery of biodegradable plant and animal remains, however, only allows a qualitative glimpse of these small isolated communities.

Although developments in Cretan agriculture and the increase in the number of Early Minoan settlements are substantiated archaeologically, the origin of the settlers is at present uncertain. Immigration was favoured by earlier scholars but there is no evidence for a break or sudden influx of population at any point between the Neolithic and the Bronze Age although improvements and changes in pottery techniques have been used as evidence for newcomers.

Recent thinking has favoured these as possibly responses to new uses and in particular the manipulation of liquids (milk, wine and oil) and new storage requirements (Sherratt 198 1: 280-281). The possibility of some migration into Crete from Anatolia is, however, not ruled out (Blackman and Branigan 1977 : 67; Warren and Hankey 1989 : 14).

Evidence of an Early Minoan I - II settlement which does have a material culture showing Cycladic affinities has been found in the cemetery at Ayia Photia about 5 km from Siteia on the road to Palaikastro (Davaras 197 1: 392-97). The cemetery consists of 252 tombs and Davaras has drawn attention to their similarity with those in the Cyclades, especially on the island of Ano Kouphonisi. A significant portion of the large collection of vases and other items from the cemetery, as yet unpublished, are said to be of Cycladic type (Watrous 1994 : 702). Analyses of bronze objects also indicate a Cycladic source for the metal (Gale 1990 : 299-316). Ayia Photia is an excellent site having access to a beach on the Bay of Siteia, fresh water being provided by a river to the west of the present village which probably covers the site of the early settlement. The area is today noteworthy for the number of olive trees.

Suspected foreign elements have also been described at Katalimata (Ierapetra), Trapeza (near Kamilari village), Gortyn acropolis and Pseira (Watrous: 1994 704). New Early Minoan I sites which were founded near older settlements, however, probably represent growth of the local population. In the case of the Lower Ayiofarango valley it is suggested that the increase in population should be seen as a continuing and growing process rather than a proliferation (Blackman and Branigan 1977 : 67). Watrous suggests that the mixing of the indigenous people with newcomers may have created the regional character of the succeeding Minoan population.

The surveys and excavations discussed above all demonstrate new sites in the Early/Middle Minoan periods. The increases at Kavousi, Vrokastro, Lasithi, Mochlos, Pseira, Gournia, the western Mesara and the Ayiofarango valley all occur in the Early Minoan period. At Kavousi growth continued in Middle Minoan I/II when the western Mesara achieved maximum growth while at Lasithi settlement is greatest in Middle Minoan III. At Palaikastro expansion of the town took place in Middle Minoan III/Late Minoan I.

It is also clear that the number of sites on Crete declined in the Late Minoan period. At Lasithi, some sites were deserted by Late Minoan III. Pseira was abandoned in Late Minoan IB.

At Gournia occupation of the countryside declines in Late Minoan III A-B. In the western Mesara, the countryside was almost deserted by Late Minoan III C. At Vrokastro, settlement on the coast declined.

Twenty five years ago Renfrew calculated the overall population levels for Crete in the Early, Middle and Late Bronze Ages based on archaeological evidence obtained from earlier surveys and excavations (1972 : 251, Table 14 IX). His comparative estimates were 75000, 214000 and 256000 persons respectively. These figures indicate 65% growth between the Early and Middle periods and only 17% between the Middle and Late periods. The estimates, therefore, show a pattern that is not too dissimilar to that seen in the site surveys.

Complementing Renfrew's estimated population figures are Whitelaw's estimates for individual Minoan settlements. His calculations are based on the minimum probable extent of archaeological sites and estimated numbers of houses. Details of these population estimates are contained in Table 43 below.

TABLE 43

## Population estimates for Early Minoan Settlements

Site	Minimum extent (ha)	Estimated number of houses	Estimated population
Myrtos	0,09	c. 5 - 6	c. 25 - 30
Mochlos	1,13	c. 55	c. 220 - 330
Phaistos	0,75	c. 75	c. 300 - 450
Mallia	2,58	c. 170	c. 690 - 1030
Knossos	4,84	c. 320	c. 1290 - 1940
Proto-palatial Knossos	c. 45,0	c. 2800 - 3000	c. 11000 - 18000

Source: Whitelaw 1983 : 339, Fig. 73

Table 43 shows that with the possible exception of Myrtos, all the Early Minoan sites listed could have had fairly substantial populations and that Knossos, Phaistos and Mallia occupied fair-sized sites, offering support to the theory that they served as redistribution centres for agricultural produce. Noting the size of the settlements and their need for organisation skills to administer them Whitelaw suggests that in the Early Minoan period "some major thresholds had been surmounted" (*ibid* : 340). However despite some conformity in broad outline between the estimated total population figures and the site surveys, some scholars are sceptical of the

value of absolute population calculations. Dickinson for example writes "the few data collected are mostly soft, relying on formulae, inevitably disputable, for converting estimates of site extent or numbers of buildings into numbers of persons" (1994 : 51).

Watrous and Branigan comment on the economic role of the first palaces. The intensive survey of the western Mesara showed that Phaistos was the largest settlement with an estimated population of 300 - 450 persons (Watrous *et al* 1993 : 224-225; Whitelaw 1983 : 339, Fig. 73). By Middle Minoan IB Phaistos was some 1500 x 1000 metres in extent and had developed into the regional centre. Signs of Phaistos' position include the architecture of the first palace, a complex administrative system for the storage and redistribution of goods, and the presence of specialised craftsmen.

Branigan notes that the economic functions of the palaces as they were first built are of crucial significance to discussion of the early state formation of Crete. Using Professor Levi's reports on excavations at Phaistos and Evans' reports on the earliest levels at Knossos he has analysed the economic functions of the first palaces (1987 : 245-249). By dividing Phaistos into six functional units and analysing the material found in them, Branigan demonstrated that three of the six units were stores (*ibid* : 246, Fig.1). Unit A was a liquids and general pottery store, Unit D contained either olive oil or grain and Unit F, pottery. Unit B contained stone items and probably represented a lapidary workshop. The evidence suggests that, from its inception, Phaistos was involved in the production, storage and consumption of both agricultural and craft products.

Through time this role progressively increased with the emphasis on storage of goods rather than craft production which remained at a low level throughout the first palace period. By phase II of the first palace, storage capacity of the west court exceeded a year's supply of grain for about 300 people. In phase III, further magazines were built, the space for pithoi being about three times that for the first phase.

Evidence from the earliest levels at Knossos is not as detailed as that from Phaistos. Indications are, however, that storage capacity was built into the palace from the start. Four *koulouras* belonging to either the initial construction period or a phase immediately following construction, could have provided a year's supply of wheat for 1000 people (*ibid* : 248). Craft

activity in the earliest levels at Knossos is not easy to document but over 400 clay loom weights point to weaving within the palace in the Middle Minoan 1B period. There is also some evidence for a lapidary's workshop (*ibid* : 249).

Material evidence from the earliest palaces at Phaistos and to a lesser Knossos, therefore, supports the models proposed for storage, consumption and re-distribution of agricultural produce. Storage of wheat, barley and olive oil expanded progressively at Phaistos and Knossos necessitating the construction of additional storage magazines. Both palaces had an early role in the regulation of local exchange of produce and crafts. MacGillivray points out that reassessment of Middle Minoan material from Knossos demonstrates that exchange took place between Knossos and Minoan towns in east Crete including Palaikastro, Zakro and Gournia (Branigan 1987 : 249, Discussion). Evidence for external trade at the first Palaces of Phaistos and Knossos is less satisfactory and does not support the level of overseas trade at this time proposed by Van Andel and Runnels (1988 : 234-247). Movement of perishable goods is, however, difficult to demonstrate.

At Mallia and Kato Zakro the economic role of the earliest palaces is less clear than at Phaistos and Knossos. Watrous suggests the case for the existence of an early palace at Mallia appears convincing, but evidence for the plan and date of construction remains minimal (1994 : 738). There is no positive evidence for workshops, no record keeping, only storerooms (Poursat 1987 : 75-76).

At Mallia, an Early Minoan II settlement has been identified, this settlement growing into a town in the early proto-palatial period (Van Effenterre 1983 : 63). The main elements of the town appear to have developed at the same time as the palace, since architectural similarities exist between the palace and the Quartier Mu in the town, situated not far from the palace (Poursat 1987 : 75).

The area controlled by the first palace at Mallia possibly extended from Gournes in the west to Chamaizi in the east and included the upland plain of Lasithi and the Isthmus of Ierapetra as far as Pyrgos in the south (Watrous 1994 : 739).

The presence of an area of land possibly controlled by the palace and the existence of pre-palatial houses highlights two emerging social trends in the pre-palatial period. The concept of tracts of land used for long term agriculture was already established, even though in the case of Mallia the boundaries cannot be accurately determined and the form of settlement emphasises communal living. At Mallia, the houses show no evidence of ranking or hierarchical distinction.

The economy at Mallia appears to have had three components. The palace with its administrative organisation, the town houses having a relationship with the countryside and the countryside itself with its agricultural potential. Storage magazines were present, in both the earliest palace and houses, often with pithoi *in situ*. While some of the pithoi were probably for oil, others contained foodstuffs since remains of cereals and legumes were found. The containers in the houses indicate that each family had its own agricultural produce. Kanta suggests that older farmhouses in modern traditional Crete may offer an insight into the Minoan economy (1983 : 155-162). She describes a village house belonging to a Monasteraki family which was built in the nineteenth century of which the ground plan is unaltered. The lower floor contains storerooms, a wine press, kitchen and stables. Pithoi in the storerooms are up to 200 years old and contain olive oil, wine, honey, wheat, beans and lentils (*ibid* : 159). In context of the pre-palatial houses at Mallia, it is pertinent that before World War II, the family grew enough produce to fill fifty pithoi, using agricultural techniques not too dissimilar to those of the Minoans.

The system used for the redistribution of agricultural produce at Mallia in the Old Palace period is unknown. However, evidence for storage facilities in both palace and houses suggests that increasing population and the need for more food led to the greater use of the agricultural land.

Whitelaw estimates that about 170 dwellings at Mallia in the Early Minoan period occupied 2,58 hectares of land housing between 690 and 1030 persons (1983 : 339, Fig. 73). In addition to storing foods for a growing population, the early palace probably functioned as the administrative centre.

At Zakro, as at Mallia, there is evidence for an earlier palace and town. Archaeological evidence suggests that there might been an earlier palace in Middle Minoan I-II. A substantial

building complex with a different orientation was uncovered under the north east part of the Late Minoan I palace. These and other remains under the later west wing together with an earlier central court date to the proto-palatial period (Platon 1971: 222-226, Figs. 125-126, 140 *cited* Warren 1987 : 49).

The town of Zakro spreads over the slopes of three hills that surround the palace, giving an impression of a Minoan harbour town somewhat similar to Palaikastro. The main axis of the street system is the harbour road which was apparently already built in the Old Palace period (Chrysoulaki and Platon 1987 : 77). This road led from the north harbour to the north east gate of the palace. The original street system was more complex but several sections had houses built over them in the Neo-Palatial period.

The houses of the town have many small rooms on the ground floor usually arranged around a larger room having access to the street. An example is the "Building North of the Harbour Road" that has numerous store rooms and an arrangement of space reminiscent of the Quartier Mu at Mallia (*ibid* 80: 80, Fig 2). As at Mallia, the houses do not indicate a social hierarchy and the finds do not suggest wealth or luxury.

Numerous storage jars were found in the store rooms of the houses, and six or seven houses contained wine or oil presses. Specific parts of the houses were devoted to the production of food such as the grinding of wheat and barley. Production and storage of agricultural produce again suggests an established relationship between town and country and emphasises that the townspeople were self-sufficient with regard to basic foods. Since agricultural products were mainly stored in the town, the town may have supplied the palace with foodstuffs.

Scanty archaeological evidence for the proto-palatial period limits reconstruction of the economy at Zakro. Furthermore it is very difficult to establish the chronological relationship between the Old Palace and the first town. A comparative study of pottery from the Old Palace and that of the proto-palatial town is needed to establish whether a well-planned town actually pre-dated the first palace (*ibid* : 80). No estimates of the Early Minoan population have been made.

The extent of palatial territories in the Proto-palatial period is difficult to determine but Bennet (1990 : 195) is of the opinion that it is likely that Knossos, Phaistos and Mallia, between them, controlled central Crete. In the likely event that the territories conformed to broad topographical boundaries it is probable that each palace headed a mini-state of between 1000 and 1500 square kilometres (Bennet 1990 : 195, Table 1), with the Lasithi Plain possibly included in that of Mallia and the Amari Plain in that of Phaistos. The situation in the east and west of the island is more difficult to assess as the exact status of such centres as Palaikastro, Kato Zakro, Gournia and Ayia Photia, in the east, and Chania in the west is still unclear in the Proto-palatial period.

As a result of damage in the Middle Minoan III period, the palatial centres were reconstructed in Late Minoan I, remaining the primary centres, responding as before to the main topographic divisions, but apparently with less agricultural storage capacity. An important new palace was built at Kato Zakro which may have been established to serve the increasingly important external trade network as imported items such as copper ingots and elephant tusks were discovered there (Bennet *ibid* : 196, footnote 20). It is also most likely that a palace, not yet identified, was established at Chania.

The largest number and the widest distribution of surviving administrative Linear A documents is also attributed to this period, suggesting that there existed a more complex hierarchy of sites with settlements such as Gournia, Ayia Triada, Archanes and Palaikastro with relatively small, but distinct central buildings and fulfilling the roles of micro-regional centres. This Neo-palatial period was also accompanied by an increase in the type of rural settlements referred to as "country houses" or "villas" with considerable storage space, which could have represented a third level of devolved control as local collectors of surplus agricultural produce lessening the need for storage capacity in the palaces (Bennet *ibid* : 197).

Agriculture in Crete in the Early Minoan period combined pastoralism with an expanding range of secondary products. Evidence suggests that wheat, barley, pulses, olive oil, wine, wool and textiles were produced. Debla in west Crete has evidence for wheat, barley and oats and also wool production in Early Minoan I. At Myrtos in east Crete there are indications of wheat, barley, oats, olive oil, possibly wine, wool and textiles in Early Minoan II.

Intensive archaeological surveys carried out on Crete confirm that substantial settlement expansion took place in the Early Minoan to Middle Minoan periods. Settlement expansion in Early Minoan I-II is documented in areas such as the Ayiofarango Valley, the western Mesara, Lasithi and Gournia.

Storage, regulation and consumption of agricultural products was a function of the first palaces at Knossos and Phaistos. Evidence from Mallia and Zakro is less satisfactory but suggests that agricultural products were stored in the town houses as well as the palaces. In the Neo-palatial period storage and other administrative functions were probably devolved to regional centres and even local estates.

Absolute population figures are difficult to estimate accurately. Estimates for population increases for the three Minoan periods (Renfrew 1972 : 251, Table 15 IX) conform in broad outline to the settlement patterns indicated by recent intensive surveys.

It must be noted, however, that none of the models proposed for agricultural settlement and population expansion in the Early and Middle Bronze Age Crete is fully substantiated by the archaeological record. Renfrew's "Mediterranean Triad" of wheat, olive and vine is jeopardised by doubts relating to the Early Minoan cultivation of the olive, and the need to include pulses which have always played an important part in the subsistence economy. Similarly, the full extent of Sherratt's "secondary products revolution" is difficult to identify since evidence of ploughs and animal traction is late, and most of the products are perishable and have not survived. With regard to trade and technology, as discussed by Van Andel and Runnels, the precise configurations of both local and external distribution and redistribution remain conjectural. There is no doubt, however, that the intensive archaeological surveys reviewed here will make a major contribution to a wider knowledge of the agricultural settlement and population expansion on Minoan Crete, particularly in the Early and Middle Minoan periods.

## 7.2 The health status of Bronze Age Cretans: The skeletal evidence

While considerable knowledge has been accumulated covering the cultural consequences of food production, the impact of agricultural subsistence on human population biology is only now beginning to be understood. The intensification of food production was long thought to herald an era of improved nutrition and health. In fact the increase in the size of human population is frequently used to support the assumption of improved health. There is, however, theoretical and empirical evidence which suggests that improved health is not necessarily a consequence of food production and that more people are fed less well. Agricultural activities and concentration on few crops often leads to changes in the environment which can increase the potential for nutritional and infectious disease. Degradation of the environment, increase of population size and density and the accumulation of waste increases the possibility of infectious disease (Armelagos *et al* 1984 : 133). How did this affect Bronze Age Crete?

McGeorge (1990 : 419) comments that our view of life on Minoan Crete has, until recently, been moulded almost entirely by the remains of the artefacts of the Minoan civilisation. "The splendid architecture of the palaces, the frescoes depicting well-dressed healthy-looking people and exquisite works of art, all combine to create the impression of a carefree privileged society" but, she suggests, the reality might have been rather different.

Certainly Minoan seals and figurines from the Middle Minoan period and frescoes from the Late Minoan period onwards, show people engaged in strenuous activities of dancing, acrobatics and, the ultimate physical challenge, that of bull-leaping. The depictions indicate lithe, well-muscled, slender but well-proportioned people, very often women, obviously representing ideals of physical development and probably relating to cult ritual. The figurative paintings are seen by experts as deriving, at least in inspiration, from Egypt (Watrous 1991 : 287-288) but the sometimes ecstatic, vigorous body movements with flying hair and limbs, are Minoan. In Crete, the frescoes as seen at Knossos, however, reflect New Palace culture and it is possible that the emphasis on the role of women over that of men, especially in processions and gatherings, reflects the dominance of a female divinity and her priestesses in that *milieu* as well as the importance of the palace as a religious centre (Immerwahr 1983 : 149). Immerwahr points out, though, that our knowledge of Minoan life is not entirely restricted to that of the palaces as miniature frescoes from Tylissos, Kea and Akrotiri on Thera give a "more normal picture of daily

life ranging from the mundane, menial tasks (water-carriers, shepherds, fishermen, rowers) to the professions (soldiers, mariners, captains and admiral as well as the *grandes dames* of the villa)" (1983 : 149). The reality of Minoan society does, however, remain elusive as unlike the Egyptian we have no literary commentary, there are no mummified remains and beliefs regarding disposal of the dead did not require reconstruction of conditions during life; funerary offerings, although interesting as artefacts, are equivocal. Minoan art, unlike that of Egypt or the Near East, tells no stories and makes no statements.

Halstead (1977 : 107), commenting on the paucity of clear evidence concerning the people themselves, notes that analyses of skeletal material are often merely appended to archaeological reports, since the findings are rarely considered to be of sufficient interest to be included in the main body of the publication.

Over the past ninety odd years, however, some research has been undertaken on skeletal material from Crete. Earlier this century studies were done by Boyd, Dawkins and Von Luschau (*cited* Glotz 1925 : 57). Seager (1909 : 301) refers to Minoan skeletal remains found in a house at Mochlos. At Kato Zakro a child's skull was found in the fill of Room XII in the west wing (Platon 1971 : 120, *cited* Warren 1986). The skull showed no pathology and it was suggested that it was that of a sacrificial victim.

The early research focused mainly on the physical types that inhabited Bronze Age Crete and related to contemporary interest in ethnic origins and indications of migrations or incursions of differing populations. The primary criterion in these studies was the cephalic index or the relationship between the breadth and length of the skull. Using this ratio the Minoan skulls were divided into three categories: dolicephalic (long headed), brachycephalic (short headed) and mesocephalic (medium headed). One such analysis of 100 skulls placed in chronological order gave the following result.

TABLE 44

Comparative cephalic indices (%) of a sample of 100 Minoan skulls

Minoan period	Dolicephalic	Mesocephalic	Brachycephalic
Early Minoan I, II, III	55	35	10
Middle Minoan I, II	66,6	25,6	7,7
Late Minoan III	12,5	50,0	37,5

Source: Glotz 1925: 58

Table 44 shows that the dolicephalic Mediterranean people predominated on Crete for the major part of the Bronze Age, their numbers only being reduced at the end of the late Minoan period. The investigation would, however, have been more useful if earlier crania had been included as it could have indicated continuity with the Neolithic stock. Minoans of Mediterranean stock were characterised by a long head, an oval face, short stature, 'olive' skin and wavy black hair, all features that can be seen on frescoes such as that of the Priest King recovered at Knossos (Sakellarakis 1982 : 119).

This kind of research is today considered to be of dubious value since it is associated with attempts to identify racial groups that are no longer theoretically acceptable. If, however, population numbers calculated from settlement data (Renfrew 1972 : 251, Table 14 IX) are read in conjunction with the data derived from cephalic indices (Table 44), the impression created is that the population increase in the Early and Middle Minoan periods took place primarily amongst the island's indigenous population.

More recent research in Aegean archaeology has begun to follow American trends and focus on anthropology as well as technology, social organisation and ideology, adding a new dimension to Classical Studies, particularly following the publication of J Lawrence Angel's seminal work in 1971 on the osteology of the people of Lerna. The techniques of contemporary demographers are used to determine age and sex-specific mortality statistics of skeletal remains as measures of health and quality of life. Life expectancy at birth, adult life expectancy, death rates during the weaning period and sex ratios of young adult deaths are among the most frequently cited parameters, together with stature and evidence of skeletal and dental pathology.

Methodological developments in skeletal biology now enable the determination of diseases of the bone that reflect environmental and nutritional stress such as retardation of long bone growth, tooth enamel hypoplasia, tooth loss, osteoporosis and porotic hyperostosis. Harris' lines of arrested development and premature osteoporosis are pathological conditions indicative of nutritional and infectious disease stress (Armelagos *et al* 1984 : 132)

Some important although rather limited work along these lines relating to Crete has been published by Becker (1975 : 217-276), Halstead (1977 : 107-111), Wall, Musgrave and Warren (1986 : 333-338), McGeorge (1988 : 47-54; 1990 : 419-428), Musgrave, Neave, Prag, Sakellarakis and Sakellarakis (1994 : 89 - 100) and this is reviewed below.

Becker examined the Middle Minoan skeletal remains found at Pezoules Kephala, Kato Zakro in 1967 and 1973 (Becker 1975 : 271-276). Representing an estimated 74 individuals, the bones provide comparative information on longevity and the number of female burials relative to males, some pathology and stature. Leaving aside 8 unsexed individuals, but including 8 possible males and 6 possible females, totals of 26 males and 40 females are obtained.

Becker's Table 1 indicates that of the males 19% died between the ages of 18 and 25, 46% between the ages of 26 and 50 and 34% survived until after 50. Of the females 8% died between 14 and 16, 13,5% died between 18 and 25, 54% between the ages of 26 and 50 and 24,5% survived beyond 50. One female described as 'a very mature adult' probably lived beyond 60. Becker remarks on the high death rate at Kato Zakro of adults between the ages of 18 and 50 but does not calculate an average life expectancy for his sample.

His investigation was mainly concentrated on the skulls since the fragmentary nature of the other bones from Kato Zakro did not allow detailed pathological examination. Certain instances of pathology in the long bones are, however, reported including "several large exostoses, arthritic lesions at finger joints, possibly two cases of spondylolisthesis (a congenital displacement of the 5th vertebra) and sinus infections". No instances of hyperostosis or osteoporosis are recorded in either the skulls or long bones.

Dental decay also affected the population of Middle Minoan I Kato Zakro. In addition to a high incidence of caries and large-scale tooth loss, extensive wear was present on the articular

surfaces of the teeth typical of populations eating a coarse milled cereal grain diet. At Kato Zakro 37% of teeth were lost before death - many individual losing almost all teeth by the age of 40 - but only 7% had caries. This latter figure is, however, probably distorted by tooth loss. Becker remarks that periodontal problems and dental disease appears to have been the most common pathology affecting almost every individual in the population.

Measurements of the fragmentary long bones and formula calculations on these show that the average stature of Middle Minoan I males from Kato Zakro was 167 cm and that of the females was 157,5 cm. Females from Kato Zakro were therefore taller than the average Minoan female, i.e. 157 cm *versus* 154,6 cm (McGeorge 1988 : 47-48). A further comparison is provided by Angel (Angel pers. comm., *cited* Becker 1975 : 274) who estimated the stature of the Middle Minoan male to be 165,4 cm and female 155,1 cm. This last estimate is 2,4 cm less than that of the average Kato Zakro female.

The above-average stature of the females recovered at Kato Zakro is complemented by the apparently larger proportion of female burials. Becker (1975 : 274, Table 1) analysed the sex and age distribution of the crania but remarks that the preponderance of female crania is not supported by evidence from the long bones.

Based on the "extremely high rate of *ante-mortem* tooth loss" and the high death rate between the ages of 18 and 50, Becker concludes that "this was not a 'healthy' group in modern terms...."

Halstead (1977 : 107ff) re-examined data from skeletal material in the work of Angel at Lerna on the mainland and Charles, in Crete and the mainland, with the intention of demonstrating the value of demographic and physical anthropological data. This work is informative as life expectancies in Early, Middle and Late Minoan Crete are compared graphically with those at the same periods on the mainland. Halstead notes that "the average age at death was low (as a rule not much over thirty for those who reached adulthood)" and that "most females died in their childbearing years (15/20 - 40 when pregnancy would have increased their vulnerability to disease and poor diet".

The graphs of Minoan Crete reveal that life expectancy for females was considerably less than that for males in the Early Minoan period (*ibid* : 109, Fig. 1). Life expectancy improved somewhat for both males and females in the Middle Minoan period (*ibid* : 109, Fig 2). This suggests that improved living conditions on the island contributed to better health and nutrition.

The Middle Bronze Age graphs for the Argolid and Lerna (*ibid* : 109, Figs. 6 and 9) support the above finding, showing increased life expectancy but at a lower level than Minoan Crete. This is compared with Fig. 7 illustrating findings from the shaft graves at Mycenae dating to the transition between Middle and Late Helladic. Both stature and teeth indicate good health but paradoxically these more privileged people died younger than their contemporaries as shown on Figs. 6 and 9. Wounds and fractures would appear to indicate injuries resulting from fighting.

Figs. 3 and 4 illustrate the demography of Late Minoan Crete. In contrast to the bulk of Middle Minoan skeletons which originated at Knossos, most of the Late Minoan remains were from Sphoungaras, a non-palace site. Though the Late Minoan I pattern of life expectancy does not differ greatly from that of the Middle Minoan period, there does seem to be a reduced life expectancy for females.

Despite their difference in origin Halstead suggests that the Middle and Late Minoan data used in the graphs document a stratum of society which was neither the highest nor the lowest.

Population numbers and longevity increased particularly in the Middle Minoan period, these social phenomena being paralleled by an expanding, more broadly based Minoan economy. In general, the life expectancies shown in Figs. 1-10 (*ibid* : 109) appear to parallel the rise and fall of the Aegean civilisations, but Halstead maintains that both in the Early and Middle Minoan periods Cretans lived longer than their mainland counterparts. He also largely discounts the predominance of male skeletons because of the probable greater failure rate of the lighter female skeleton to survive.

Wall, Musgrave and Warren (1986 : 333-383) have published a full osteological report on recent excavations on Crete where the bones of young children were found in a room of a Late Minoan 1B house occupying the north-eastern end of the Knossos stratigraphical museum. While a few groups of bones were still articulated, they were for most part separated from one another.

The authors suggest that the bodies were thrown into the room with one or two parts still held together. Because of the mass of loose bones and skull fragments the total number of individuals represented was not easily determinable. The remains of two skulls, together with a fragment of a third indicate the presence of at least three children - probably four since the remains of four right femora and of four left tibiae were identified.

More children's bones were found in the Late Minoan 1B destruction fill of the Room of the Frescoes in the north-east part of the house. These bones include a left clavicle, ulna and radius, two femora fragments, a skull fragment and a metatarsal. In addition two skull fragments, a tooth, a vertebra, rib, radius, twelve phalanges, a femur, two tibiae, four fibula fragments and two metacarpals were recovered from a drain outside the house. The find of the left clavicle could indicate a fifth child if the bones from the Room of the Frescoes are from the same assemblage as those in the Room of the Children's Bones. In addition the bones from the drain, if taken separately, could represent two further children making a possible total of seven.

In order to establish the health and condition of the children at the time of death radiographs were made of the two reasonably intact skulls and selection of bones including mandibles, a clavicle, scapula, humeri, femur, fibula, ulna, radius, eight hand phalanges and nine metatarsals. None of the bones showed any evidence of pathological abnormalities. There was no evidence, for example, of Harris' lines of arrested development indicating malnutrition or infection.

The authors of the report concluded that, given the good health of the children, they were unlikely to have died naturally and that the clue to the children's deaths probably lies in butchery marks present on the bones and accompanying ceramic evidence indicating a ritual context. The assumption is that the children were victims of a sacrificial murder.

McGeorge, in what is probably the most extensive investigation to date, examined some 8000 Minoan bones using techniques that included macroscopic, microscopic and X-ray examination. The human skeletal remains described in her publications (1988 : 48-54; 1990 : 419-428) appear to have included some 410 individuals recovered from the archaeological sites below:

Early Minoan	Agios Haralambos, Myrtos, Palaikastro, Platyvrola
Middle Minoan	Ailias, Chryssolakkos, Gypsadhes, Monastiraki, Kephali, Myrtos, Nochia.
Late Minoan	Armenoi, Aghios Syllas, Delianna, Galia, Pigi, Paphlagos, Sellopoulo, Stravromenos

Source: McGeorge 1988 : 47

Of the 18 sites listed above, only two were noteworthy for the quantity and preservation of the human remains, namely Early Minoan Agios Haralambos, Lasithi and Late Minoan IIIA-B Armenoi, Rethymnon.

McGeorge states that "what is surprising is that with the passage of time (and one assumes from the archaeological evidence, better living conditions) the average life expectancy of the Minoans decreased rather than increased" (1988 : 48). She repeats this impression of a "downward trend" in ages of death in the 1990 paper but accompanies it with a table (1990 : 420, Figure 2) indicating that the average ages of death remained *reasonably constant* at approximately 35 years for males and 28 years for females right through the roughly fifteen hundred years from Early Minoan to Late Minoan periods, only dropping in Post-Palatial Late Minoan IIIA-B to 30 years for males and 27 for females. It would also appear that this last figure is taken from the 274 individuals from the Late Minoan III cemetery at Armenoi only and is not representative of the period elsewhere although the findings would tend to confirm a deterioration in living standards at this time.

Peak female mortality was between 20 and 25 years, the period of maximum reproductive activity, suggesting that pregnancy and lactation diminished resistance to disease. Despite the rather bleak picture of life for women in Minoan times, some did survive beyond 50 years. Interestingly, McGeorge's data indicate that Cretan life expectancy in the Post-Palatial period was possibly slightly less than that of the mainland.

Bones recovered from the cemetery at Armenoi also provided information on infant and juvenile mortality at this time (McGeorge 1988 : 48; 1990 : 425-427). Children under 15 represent a third of the remains, a high figure that can, however, be compared with 56% infants and juveniles in the Middle Bronze cemetery at Lerna (Angel 1971 : 109). The relatively high numbers of infant and juvenile deaths on Crete is attributed to interrelated factors such as lack of

hygiene, childhood diseases and poor nutrition (McGeorge 1988 : 48), but here again the reference is to a very late period. Halstead points out that a high level of child deaths is documented in many ethnographic and historical studies and that in 1928 nearly 25% of those born in Greece died during childhood (1977 : 107).

McGeorge's measurements of 1000 limb bones reveal that the average stature of Minoan males was 167,6 cm - only 0,5 cm below that of present day Cretans - while that of Minoan women was 154,6 cm. Unlike Angel at Lerna, however, McGeorge does not comment on the body build and possible appearance in life of her subjects of study.

The *post-mortem* condition of teeth provides indications for health and nutrition during life. Examination of skulls (again from the cemetery at Armenoi) showed 28,6% of teeth were lost before death and 17,7% had caries. These figures are double those for caries (9%) and tooth loss (13,3%) reported for the Middle Minoan period at Knossos (McGeorge 1990 : 423). This greater frequency of dental decay present in Late Minoan III teeth is attributed to dietary change that emphasised greater dependence on foods with a higher carbohydrate content (*ibid* : 423-424). If this theory is correct it would imply that the growth of towns and increased specialisation created a preference for foods that could be dry-stored with minimal deterioration. On the other hand dental disease was rampant at Middle Minoan Kato Zakro as shown above, but dependence on carbohydrates could have taken place at an earlier stage at this site.

Permanent marks present on bones such as Harris' lines of arrested development form non-specific evidence for diseases that can be caused by nutritional deficiencies due to seasonal food shortages. Typhoid, malaria and brucellosis may similarly leave evidence of pathology on bones. Defective tooth enamel can indicate childhood diseases such as measles, chicken pox or scarlet fever. McGeorge (1988 : 50, Table 4) lists eighteen forms of palaeopathology she identified. Included are infectious diseases both bacterial and viral, cancer, brucellosis, tuberculosis, sarcomas, arthritis, osteomyelitis and osteoporosis. She also claims "cases of iron deficiency anaemia, *possible* (my italics) cases of rickets and scurvy in children" (*ibid* : 52). The presence of bone fractures indicates tough living conditions but there are indications that the Minoans knew how to reduce and immobilise broken bones.

Unfortunately McGeorge does not indicate the incidence of the lesions or the diseases which she identifies and states that it is not possible to establish the prevalence of any particular disease amongst the Minoan population, commenting only on the "high frequency" of deficiency diseases and the increased incidence of *ante-mortem* tooth loss in females (1990 : 421-422), and remarking that the incidence of osteoporosis in the Minoan population appears "disproportionately high" compared to the low mean life expectation of the population (*ibid* :53).

Since, however, it would appear that 66,8% (274 out of 410 individuals) of McGeorge's material was sourced from the cemetery at Armenoi, the degree of pathology cannot really be representative of other sites in Late Minoan Crete, let alone other sites from other periods. Taken in conjunction with the survey findings relating to settlement decline and abandonment during this period, however, the findings are interesting.

Musgrave, Neave, Prag and E and JA Sakellarakis have recently published the findings on two skulls recovered from a Middle Minoan II-III shrine at Anemospilia at Archanes (1994 : 88-100). The primary purpose of the study was the reconstruction of the facial features of a Minoan male and female tentatively identified as a priest and priestess whose skeletal remains represented two of four individuals recovered from a shrine in which they had been trapped in an earthquake.

Examination of the skull of the priest showed that the cranium was much damaged, probably as a result of burning and the weight of overlying deposits. Evidence of separation of the inner and outer tables of the cranial vault was present, especially in the supraorbital regions of the frontal bone. The maxilla was poorly preserved and only two upper teeth were recovered in their sockets, the very damaged second and third molars on the right side. The mandible was almost intact. Apart from a trace of *cribra orbitalia* in the roof of the right orbit no pathology was present in the bones of the cranial vault which were not thickened in any way. The conclusion was that the skull was that of an apparently healthy male aged between 30 and 40 years.

The skull of the female was better preserved with no evidence of burning. The skull vault was well represented, the frontal bone complete as were the upper parts of the parietals and occipitals. The right half of the maxilla was well-preserved and the central and lateral incisor

teeth present. One tooth had been lost before death. The woman's estimated age of 20 to 25 years contrasted sharply with the fact that the sagittal and lambdoid sutures were completely, and the coronal almost completely, closed. This aberration was considered to be associated with the thickening of the skull vault (11-13 mm) (cranial porotic hyperostosis) and osteoporosis of the outer surface of each parietal, suggesting that she suffered from acquired or congenital anaemia. The woman's teeth were generally sound and she seems not to have suffered from caries although the presence of calculus indicates poor dental hygiene.

Reconstruction of the facial features of the priest indicates an impressive middle-aged man with fine proportions to his face. He had a strong jaw and wide sloping forehead (Musgrave *et al* 1994 : Fig. 6, Plates 14a and b). Reconstruction of the priestess reveals an attractive young woman with a wide forehead and classically female proportions to the rest of her face. Her hairstyle, added on the basis on Minoan art, shows long locks hanging over her shoulders with a series of small curls framing her face (*ibid* : Plate 14c and d).

The authors point out that these two facial reconstructions offer the first indications of the real appearance of the Minoans, as opposed to their own conception of their appearance as seen in their art. What we are presented with is two physically attractive people who held reasonably high status in a community which had considerable influence in the Bronze Age Aegean. Musgrave *et al* remark that whereas Minoan art conveys a certain prettiness about its characters, there is nothing 'soft' about either of these two individuals. Sadly, examination of the post-cranial remains of these people did not form part of the authors' brief so we have no idea what the rest of them looked like! The excavators of the site report, however, that the height of the male was "six foot" i.e. 183,0 cm (Sakellarakis & Sapouna-Sakellarakis 1981 : 222). How much the reconstructions resemble the originals is, of course, a matter for debate.

The amount of data related to the demography of the Minoans is limited but a few tentative conclusions can be made. It must be noted, however, that these must be regarded with a certain degree of reservation for many reasons. The preservation and recovery of skeletal material in Crete is fortuitous, from differing social and economic sources, very often fragmentary and the sample is always pathetically small. The evidence can be distorted by differing ways of disposing of the dead, multiple burials and the use of ossuaries, together with possibly varying attitudes to the dead of differing age, sex and social class. In particular the ratios of subadult

remains can be inaccurate because of the friability of juvenile bones. Moreover, causes of death related to such imponderables as epidemics, natural disasters and blood feuding for example cannot even be guessed at.

The accuracy of estimates of age and sex is crucial to conclusions and has to be relied upon and these estimates are admitted to be extremely difficult even for the most experienced osteologists. McGeorge notes that her diagnoses must be treated with caution since they rely on clinical and radiological appearance of bones. She points out that even today, with sophisticated clinical and laboratory tests on individuals who are living, it can be very difficult on occasion to obtain a diagnosis. It follows that the conclusions of the authors of reports also have to be examined carefully as it is possible that, depending on emphasis, different interpretations can be placed on the same data particularly as it is the nature of the work that abnormalities are sought and remarked upon whereas this is seldom the case with the ratios of normal to abnormal findings.

In this context it must be pointed out that there are problems with McGeorge's 1988 and 1990 publications and the sweeping conclusions relating to Minoan demography that are made. This is particularly the case since they represent the most thorough osteological work that has been carried out on Bronze Age Cretan material and consequently of considerable importance and influence.

The apparent incompatibility between her figures and her conclusions relating to "trends" in average death ages has been commented on above. The rather unsystematic presentation of the papers makes it necessary to glean information from both documents and attempt to understand on what basis her interpretations are made. In the first place the sample for the whole Early Minoan period (36 individuals over roughly 800 years spread over four sites) and the Middle to Late Minoan periods (100 individuals over roughly 650 years spread over at least seven sites) (1988 : 47; 1990 : 420), is extremely small. The lumping together of the remains from multiple sites all over Crete also precludes any assessment of the material related to individual sites or even areas.

The Late Minoan IIIA-B sample of 274 individuals (representing 66,8% of the total) (1990 : 420) from a single site (Armenoi) over roughly 200 years is rather better but tends to

weight the sample disproportionately, so that any statistics relating to average age at death or bone pathology from this group will dominate and in this case, it seems, be imposed on the whole Minoan population.

Analyses are also not wholly comparable. Halstead, for example, does not include Becker's Kato Zakro report in his analyses since he maintains that the age groupings are too wide. Scientific examination of skeletal material is in its infancy and very much more work needs to be done particularly in associating skeletal remains with grave goods indicating their social and economic status. That being said, however, a degree of correlation does exist although there are contradictions.

### **Summary and discussion**

Demographic data for Crete calculated from settlement numbers used in conjunction with craniological measurements suggest that population expansion in the Early and Middle Minoan periods occurred mainly amongst the indigenous population.

Male skeletal material recovered archaeologically outnumbers female (the exception being Middle Minoan I Kato Zakro where females outnumber males), but this may possibly be generally discounted because of differing survival rates for male and female bones.

According to the papers reviewed above, average life expectancy on Minoan Crete was low, under 35 years for males and approximately 28 for females. A few individuals of both sexes reached 50 years, even fewer 60 and the exceptional person achieved 70.

It is interesting to compare these data with those of Angel who arrived at an average age of death for the Palaeolithic of 33,3 years for men and 28,7 for women and for the Neolithic at Catal Huyuk 34,3 for men and 29,6 for females (Angel 1971b, 1972, *cited* Hassan 1984 : 102). During the late Neolithic, samples from eastern Mediterranean (Macedonia, Leukas and Acarnia) indicate that the average ages of death for males was 33,9 and females 28,6 (Angel 1972). These figures would appear to suggest that there was little or no difference in life expectancy between the Palaeolithic, Neolithic and Bronze Age populations.

Angel's findings, however, indicate that in the eastern Mediterranean during the Bronze Age there was a slight increase in the average age of death, i.e. Early Bronze Age (3000 BC) males 33,7, females 29,5; Middle Bronze Age (2000 BC) males 36,3, females 30,8; Late Bronze Age (1500 BC) males 39,4, females 32,1 (Angel 1972, *cited* Hassan : 103).

These figures, although somewhat contradictory, are comparable with other early societies (Angel 1971 : 70; McGeorge 1990 : 421) and indeed with other European societies until relatively recently (except that in all countries for which modern statistics are available, the expectation of life for women is greater than that for men). For example, in England and Wales in 1840 expectation of life was approximately 40 years for males and for females in Colonial America it was 35 years. (Black 1987 : 257).

Increased life expectancy has been a feature of the Twentieth Century AD rather than before - the increase between 1840 and 1880 being only one year for each sex as contrasted with the very great increase between 1940 and 1970. In 1977 the average life expectancy was 70,3 years for men and 76,3 for women and still increasing but more slowly. In contrast, however, at the same time the statistics for Ethiopia were 37,5 years for men and 40,5 for women (*ibid* : 257). The improvement therefore is still largely applicable to those who have access to unpolluted, clean water and hygienic sanitary practices, modern medical and surgical techniques, drugs (particularly antibiotics) and a balanced diet throughout the year. Since these are very new advantages it may be seen that up to almost the present time the whole development of civilisation, or Western civilisation at any rate, has been dominated by young people.

Increased life expectancy of the modern magnitude, together with a drastically lowered infant and child death rate is not necessarily advantageous in terms of availability of resources. The "population explosion" in modern times is becoming increasingly less sustainable and the large proportion of aged people lays a heavy economic burden on modern "First World" society. It could be conjectured that in Minoan Crete (as in Eighteenth Century South Africa in the rural pioneering society), a smaller number of stronger male individuals survived and reproduced over an extended period probably with a succession of females, most of whom died young exhausted by multiple pregnancies. Even if only the stronger half of the offspring survived, an increase in the population resulted. Few aged and unproductive people had to be supported by the group

and a balanced population dynamic resulted. The Minoan economy would have lacked the strategies to cope with the modern situation.

In the Middle Minoan period life expectancy for both males and females, in particular those in the middle stratum of society, improved somewhat and Halstead claims that Cretans lived longer than mainlanders at the same period (see Halstead above). At Knossos, however, a number of males achieved 60 years with some even reaching 70. Fewer females achieved 60 with some reaching 65 years (Halstead 1977 : 109, Fig. 2). This improved life expectancy on Crete in the Middle Minoan period was associated with an increased birthrate which is demonstrated demographically in the increase of settlement numbers. Increased longevity and better health, as seen from population growth at Knossos and the increased numbers and stature of women at Kato Zakro, is attributed to improved living conditions. These populations were, however, associated with palace economies and the likelihood exists that living conditions were better at these centres than generally on the island.

McGeorge's findings relating to the decline in life expectancy in Minoan Crete, based mainly on her investigation of the bones which originated mainly from an Early Minoan site (Agio Haralambos) and a very late one (Armenoi), indicate that average life expectancy for males declined to 30,8 years by Late Minoan III and that for females to 27,3. The reduction in life expectancy was accompanied by greater dental decay, with both tooth loss and caries being more prevalent in females. This higher incidence of dental and other pathologies may reflect the demographic and dietary changes that took place at the end of the Late Minoan period. Dickinson (1994 : 88) suggests that agriculture was again directed mainly towards subsistence and thus towards cereals and pulses than the orchard crops which required such an investment of labour and time. The livelihood of the community depended chiefly on animal husbandry and value products such as woollen textiles for trade exchange as evidenced by the imported vases and other valuable objects found in the tombs. The animals were seldom slaughtered for meat as they were too valuable for other purposes (McGeorge 1990 : 424).

McGeorge also suggests a possible correlation between a high carbohydrate diet and low life expectancy, citing as supporting evidence studies carried out in India. In this particular dietary survey carbohydrates made up 80% to 90% of the diet and the average life expectancy was 26,9 years for males and 26,6 for females. Comparing this with Armenoi, McGeorge states

that a grain diet is normally low in calcium, vitamin C and iron. Armelagos *et al* (1984 :146) point out that the outer husks of cereal grains contain phytic acid, a substance that combines with the phosphorus in the grain to form phytates. These compounds can be broken down during processing by the action of yeast or cooking. When such practices are absent or inefficient, phytate phosphorus may interfere with the absorption of calcium and to a lesser degree iron.

Archaeological and nutritional evidence presented earlier, however, confirms that the Minoan diet broadly conformed to criteria for the traditional Mediterranean diet. These criteria postulate that the carbohydrate fraction of the diet should exceed 50% (Giacco and Riccardi 1991 : 8-9, Fig. 1-2). Published data for the rural Cretan diet lists a carbohydrate content of 49,4% (Menotti 1991 : 238, Table 12-1). This figure is 30% to 40% lower than that of the Indian diet which McGeorge cites as offering a possible parallel but, as McGeorge points out, in the Late Minoan III period at Armenoi the diet had a high carbohydrate content, probably higher than earlier periods in the Bronze Age and fresh meat was seldom eaten (1990 : 424).

Examination of Late Minoan I children's bones revealed no evidence of malnutrition or any other form of pathology. This offers support to the assumption that health and nutrition improved at this time. At Armenoi by Late Minoan III, however, juveniles and infants composed a third of burials in the cemetery at Armenoi. (This figure, although high, is still 22,6% lower than that at Lerna.)

Good stature is generally accepted as evidence for a reasonable standard of nutrition but is also genetically determined. The heights calculated for Minoan men and women correlate strikingly with the European Mesolithic and Neolithic averages of 167,5 cm for men and 154,7 cm for women (Meiklejohn and Zvelebil 1991 : 133), and with Angel's figures for Middle Helladic Lerna of 167 cm for men and 154 cm for women (Angel 1971a : 110). Measurements also reveal that the Minoans were, on average, 6,4 cm taller than the Late Helladic people (McGeorge 1988 : 49); 12% of McGeorge's sample exceeded the 171,5 cm stature of the persons buried in the shaft graves of Mycenae which is attributed to a better diet enjoyed by a privileged social class (Angel : 1973, *cited* McGeorge 1988 : 48).

The above data would appear to be generally supported in Dickinson's review of the Aegean Bronze Age (1994 : 88-91). Reiterating the assumption that health and nutrition were

probably optimum in Crete in the Middle Minoan period, he points out that all the larger bone samples provided very similar average heights and that these averages are only 0,5 cm lower than modern Greece. He suggests, furthermore, that the male/female distinction may reflect a socially instilled obligation to feed males of the household better than females, a practice which prevails in many third world societies today.

Examination of the skull of the 30-40 year old Middle Minoan II-III male, probably that of a priest, prior to reconstruction showed no pathology except tooth loss. That of the accompanying female showed porotic hyperostosis associated with anaemia. It is interesting that porotic hyperostosis is not reported by either Becker or McGeorge (although McGeorge mentions possible cases of iron deficiency anaemia) (1988 : 52). In contrast, it was demonstrated in 26% of juveniles and 16% of adults at Lerna (Angel 1971a : 110) and in 50% of individuals at Franchthi cave (Angel 1967, *cited* Meiklejohn and Zvelebil 1991 : 130). Angel thought that the condition was mainly associated with the congenital Mediterranean anaemia - thalassaemia - since he was under the impression that the heterozygous form of this haemoglobinopathy offers protection against the malarial parasite (Angel 1967 : 378-389). Recent study suggests, however, that acquired anaemia, in particular that caused by iron deficiency, may have brought about more of the skeletal changes than the congenital form (Stuart-McAdam 1988 : 284-287, *cited* Musgrave *et al* 1994 : 91; Sallares 1991 : 275-277).

Unless the skeletal changes associated with anaemia have been missed or not reported, this condition does not appear to have been widespread in Crete. It seems also that the incidence of porotic hyperostosis which Angel associated with malaria has subsequently been shown not to correlate satisfactorily with the incidence of that disease. The mosquito-borne parasite *Plasmodium vivax* which causes the severe form of malaria probably did not reach Greece until the first millennium BC (when it was to cause severe debilitation of the population lasting until the twentieth century), although the milder form could have been there earlier (Bruce-Chwatt and Zulueta 1980 : 16). This could also indicate a low incidence or absence of malaria in the Bronze Age both on the mainland (contrary to what has previously been accepted) and in Crete.

Tooth loss and caries were generally features of the Minoan material examined and have been associated with dietary deficiencies and infections resulting in developmental defects (such as enamel hypoplasia), poor dental hygiene and wear due to unrefined foods and grit in the

cereals consumed. Unfortunately, except for one tooth with evidence of enamel hypoplasia reported by McGeorge (1988 : 50), there is no real evidence for the cause of tooth loss in the Minoan population.

Carbohydrate consumption is again implicated as being critical to caries development. Dietary carbohydrates particularly sugars affect plaque pH, increasing acidity to the point where dental enamel is dissolved. Dietary protein results in increased alkalinity of the plaque, leading to mineral crystallisation and calculus. The presence of both caries and calculus indicates alternate periods of carbohydrate and protein dietary sources but not does not necessarily indicate deficiencies associated with them. High incidence of caries has been described in European mesolithic populations associated with botanical remains of fruits, nuts, berries, legumes and cereals (Meiklejohn and Zvelebil 1991 : 132). Perhaps the Minoans developed a sweet tooth!

Dental problems together with the reportedly high incidence of osteoporosis could indicate a calcium deficiency in diet. Allbaugh (1953 : 120-121) notes that the calcium intake in the modern Cretan diet would appear to be the least satisfactory of all elements but that the high proportion of calcium in the environment and the water means that all dairy products and vegetables would have a greater calcium content than usual. The utilisation of the mineral by the body should be high since this is assisted by vitamin D which is readily synthesised in the sunny climate of Crete. These factors would not have changed over the years and the reported possible incidence of rickets in the Minoan population is puzzling, but actually again probably refers to the Armenoi sample and once more could be attributed to a high grain diet or possibly intestinal parasites such as the dog tapeworm, which could have compromised an otherwise high quality diet in terms of benefit to the individual (Zvelebil and Meiklejohn 1991 :130-131).

It should be remembered, however, that until the advent of modern dentistry and emphasis on dental hygiene techniques, such as regular cleaning and the professional removal of calculus, there was a very high incidence of tooth loss in all societies due to caries and also the gum infection *pyorrhoea alveolaris*, said to be the one of the most common and intractable diseases in the world until recently. Also until recently, the only cure for an aching tooth was its removal and there is evidence that tooth extraction was practised from early on in Crete (McGeorge 1988 : 52).

McGeorge's comments on the "disproportionately high" incidence of osteoporosis (1988 : 53) again probably refer to the Armenoi population, but are applied to the population as whole, which is questionable. This progressive and generalised loss of bone matrix which makes bones brittle is today associated with falls and fractures in the elderly, frequently being a terminal event in life. In the Minoan population the incidence of osteoporosis contrasts with the young age at which it has been reported by McGeorge, suggesting reduced bone mass in the post-pubertal adult to start with, resulting from deficiencies during growth. While osteoporosis is a normal feature of advanced ageing, its occurrence at a younger age is an important indicator of stress. Juvenile osteoporosis has been shown to result from protein-energy malnutrition (Armelagos *et al* 1984 : 141). Multiparous females are particularly at risk since their reserves of calcium and energy are likely to become depleted. Lactation alone requires up to 300 mg of calcium and 1000 kilocalories per day (*ibid* : 146). This could explain both tooth and bone loss in this context.

With regard to protein levels, meat consumption has traditionally been low on Crete, primarily because the people were economically dependent on their animals for traction, wool, milk and cheese. Even today meat consumption is low, a saturated fat intake of 7,7% of total calories confirming this characteristic of rural Cretan diet (Menotti 1991 : 328, Fig. 12-1).

Possible indications of scurvy were identified by McGeorge and a deficiency of vitamin C could also have been related to tooth loss. Fruits, vegetables and tubers, the principal sources of the vitamin, are generally seasonal which often leads to seasonal deficiencies of the vitamin. Furthermore vitamin C is unstable and soluble in water, leading to its destruction during cooking (Wing and Brown 1971 : 39). Modern Cretans obtain nearly all their vitamin C requirements from citrus and tomatoes and these were not available in Minoan times (Allbaugh 1953 : 115).

Bone lesions suggestive of fractures, degenerative diseases such as arthritis arising from trauma or hard work and deficiency diseases such as those associated with tooth pathology, anaemia, scurvy and rickets have, therefore, been identified and discussed but at present their general incidence is not quantifiable. It does seem possible that Becker could have perhaps over-emphasised the interpretation of tooth loss at Kato Zakro, particularly as he was interpreting it from a modern point of view. The problems relating to McGeorge's work have been discussed above.

Probable causes of death in Crete, many of them early as in all societies prior to the 20th Century, were accidents, uncontrollable infections and sepsis, food poisoning, childbirth, internecine violence and natural disasters such as earthquakes and storms. Some diseases such as diphtheria would not yet have been known and some, such as tuberculosis and brucellosis said by McGeorge to be endemic at Armenoi (1990 : 424), were associated with close animal contact and the use of contaminated dairy products. Tetanus and gas gangrene are described in contemporary Egyptian medical papyri. Even in the mid-20th Century a young foreign couple living close to the rural population in Crete reported suffering from food poisoning, boils, typhoid and appendicitis which nearly proved fatal, and certainly would have done in earlier times (Doren 1994 : 175-184).

Among the Minoan population, as among all known societies, there would have been traditional healers and healing processes to which people resorted in times of sickness and trouble. Connections with Egypt would have probably revealed the medical practices current there including the use of splints, bandages and compresses. There is also a reference in the hieratic Ebers papyrus c. 1580 BC which mentions medicinal herbs in connection with the Keftui (Cretans) (Sakellarakis and Sakellarakis 1984 : 198).

More reliance was surely, however, placed on the supernatural agencies which were seen to control the whole of life processes. The healers would probably have been priests or closely allied to priests and archaeology has revealed the peak sanctuaries at which supplicatory sacrifices and offerings were made. Among the offerings are clay models of male and female figurines, arms, legs, heads, hands, women crouching in childbirth and phalli which poignantly indicate the sites of afflictions (Watrous 1994 : 731-734).

There is also the probability that living conditions in the island varied greatly and that in some subsistence farming communities removed from the economic centres and particularly where the land was poor, considerable hardship existed, whereas at the palace centres and environs food was more plentiful and labour less arduous. Considerable variation in nutrition within a given community in all probability also existed. Leaders, priests and priestesses, talented and skilled individuals and possibly young children would have fared better than the general population and been expected to do less hard physical work.

The question which must inevitably arise from the examination of such physical anthropological background of the Bronze Age Minoans as is available to us, is that suggested by McGeorge: Was the reality very different to the lively representations of Minoans we see in frescoes and other paintings and also from the romantic conceptions of Sir Arthur Evans?

Perhaps the point to bear in mind is that, unlike the Indian example where much reliance is placed on one staple cereal, Crete has always offered a varied diet. Even if the carbohydrate content was excessively high, it would be supplemented by typical Cretan products such as olives, olive oil, legumes, fruit and fish. These foodstuffs should contribute vitamins, minerals and fatty acids to a diet that they might otherwise be lacking and would have been utilised until intensification of cereal agriculture and dependence on stored foodstuffs superseded them in the Late Minoan Post-Palatial period.

There would seem to be little reason to doubt the evidence of the frescoes up to the time of the destruction of the palaces and that the pathologies reported by McGeorge were a characteristic of the last phases of Minoan Crete. The vigour, ingenuity, originality and adventurous spirit displayed by the Minoans up to this time, are all characteristics of a society of predominantly disease-free young people although they probably aged relatively early as they fell prey to the life-threatening and life-terminating hazards discussed above, against which they had no defence. A few older doubtless strong and tough experienced people survived to administer, educate, advise and provide some equilibrium but not so many as to become a burden or impose too conservative restraints.

The artefacts and paintings relate to and emphasise the intense preoccupation of the Minoans with their religion. There are numerous votive figures and figures seen in positions of adoration and or supplication. We see ritual activities and processions, altars, priests, priestesses and animal sacrifice. What is not shown however, and which is demonstrated in the skeletal evidence reviewed above, is that human sacrifice and even possibly ritual cannibalism were also sometimes practised, probably usually involving children as in the Near East. It is thought that the priest and priestess at Anemospilia were engaged in human sacrifice at the time of their death (Sakellarakis and Sapouna-Sakellaraki 1981 : 204-223).

The Minoans, therefore, were faced with much the same constraints of life expectancy and health as other early and modern primitive societies. For a period of about fifteen hundred years over some 50 to 60 generations, however, it seems that there were certain predisposing factors on Crete which stimulated in the people a creative energy and vigour of mind which enabled them to develop a civilisation which generated the social and economic organisation, architecture and artefacts which were the subject of McGeorge's comment quoted at the beginning of this section. Furthermore, as Warren points out, "the art found in the palaces reflects a vitality and humanism that distinguishes Crete from contemporary societies such as Egypt and Assyria. The origin of the European tradition of humanism and individualism is generally attributed to the Greeks, but there is a sense in which Minoan culture can be considered as the first example of a distinctly European tradition" (Warren 1985 : 74).

## **8. THE ROLE OF THE TRADITIONAL MEDITERRANEAN DIET IN THE DEVELOPMENT OF MINOAN CRETE: SUMMARY AND CONCLUSIONS**

### **8.1 Prehistoric background**

Despite the number of archaeological excavations in Crete over the last 100 years and the large number of Bronze Age artefacts and architectural remains that have been unearthed, we really know with certainty relatively little about the people that Sir Arthur Evans named "Minoans". Informed conjecture and deduction from archaeological and ethnographic evidence tells us that about 8000 years ago a courageous group of people, already practising a farming rather than a hunter/gathering economy, had strong enough boats to bear themselves and animals probably from the Near East, to the island where they settled at Knossos, built stone and brick houses and farmed with the exogenous animals and cultigens (goats/sheep and cattle, wheat and barley) they had brought with them.

During the first two and a half thousand years nothing much happened except some growth in the Knossos settlement and some maritime contacts. The next two and a half thousand years, however, saw the rise and decline of the influential Minoan civilisation contemporaneously with that of Egypt and those of the Near East. From about 3500 BC, increasing external contacts and general technological advances particularly involving the use of metals, animal traction and products and the exploitation of new plant domesticates (including olive and grape), appear to have triggered relatively rapid population growth and expansion of settlements which ultimately resulted in highly organised regional economies. These were based in centralised 'palaces' of complex architectural design at Knossos, Malia and Phaistos, the first of which were destroyed about 1700 BC but rebuilt with even greater sophistication with additional palaces at Kato Zakro and probably Khania, which controlled both internal and a flourishing external trade. A system of writing (Linear A and Hieroglyphic) was developed to record transactions and regulate palace practices.

At the height of their prosperity as a trading and naval power in the Mediterranean, about 1550 BC, the Minoans appear to have gradually exerted influence over proto-Greek speakers from the mainland and in turn been greatly influenced by them. Their writing was adapted to the

new speech (Linear B) and there was a meteoric flowering in the Late Middle Minoan and early Late Minoan period when they first depicted themselves in wall paintings and seals together with other local and foreign scenes. This period was all too brief and by 1400 BC the palaces were destroyed and the mainland had prevailed, controlling Crete from a partially rebuilt Knossos. By 1200 BC Minoan Crete was a spent force and by 900 BC its dynamic past was dimly shadowed in the legends which preserved such names as Minos, Pasiphae, Ariadne, Rhadamanthys and Daedalus and which were to provide a tenuous continuity between Bronze Age and Classical Greece.

The people represented in Minoan paintings and model figures are characteristically almost invariably young, slender, well-proportioned, lively-looking and in the case of males, well muscled and athletic. All have long, wavy and lustrous hair. They are often engaged in active pursuits wearing colourful and intricately patterned clothes which emphasised their sexual attributes without any suggestion of lasciviousness. The famous bull-leaping sport or ritual must have required such superb fitness and training and been so dangerous that even today no gymnast would attempt it. They appear to have seen themselves as a daring and confident people who worshipped their gods standing proudly and also in ecstatic dances in which women played an important part. They certainly were also a clever and innovative people who evolved an original system of writing and produced potters, painters, jewellers and architects whose creations were admired and copied throughout the ancient world and which have been wondered at ever since their rediscovery.

## **8.2 Archaeological and nutritional conclusions**

- (a) Study of the archaeological, faunal and literary evidence confirms that the food consumed in Bronze Age Crete broadly conformed to what is today identified as the traditional Mediterranean diet. Modern studies of Crete appear to confirm that this has persisted basically unaltered on the island for at least the last 4000 years and possibly longer.

- (b) The primary nutritional features that identify the traditional Mediterranean Diet are:
- \* A high cereal content that provides between 30% and 60% of the daily *per capita* calorie intake,
  - \* an olive oil intake of up to 60 grams *per capita* per day,
  - \* a saturated (animal) fatty acid intake that represents less than 10% *per capita* calorie consumption per day related to a low meat and dairy products component,
  - \* supplementary fish as an alternative source of protein and, incidentally, n-3 fatty acids.
- (c) Evidence indicates that the primary components of the traditional Mediterranean diet were developed as a consequence of agriculture-related activities that took place over the previous 4000 years from the Neolithic to the Bronze Age. The domestication of the olive (and olive oil production) was probably the final component, only becoming available towards the end of the Early Minoan period.
- (d) The archaeological recovery of wheat and barley on Crete, together with Linear B records for quantities of grain and architectural evidence for storage facilities, substantiate that cereals were important components of the Minoan diet.
- (e) Olive cultivation and olive oil production are confirmed by the recovery of olive stones and wood, presses, separators and containers also Linear B, which provides some idea of the size and location of Minoan olive groves. Analysis of the evidence indicates that central and eastern Crete were important olive growing areas in the Middle and Late Minoan periods.
- (f) On Crete and the Aegean islands a low intake of meat was usually supplemented by fish which provided an alternative source of dietary protein and also polyunsaturated fatty acids.
- (g) Synthesis of the faunal, literary, art, and taxonomic evidence for Minoan and Aegean fishing indicates that sub-tropical Atlantic fish formed a substantial component of fish caught. Fish identified were mainly smaller inshore species that included mullet, sardine, mackerel, squid and octopus. These fish were supplemented by catches of migrating tuna, one potential resource being presently located to the west of Crete.
- (h) Current medical and nutritional research indicates that the Mediterranean diet offers various health benefits. Research has tended to concentrate on reduction in heart disease and some cancers as they are modern problems, but it is likely that these benefits are associated with other general health advantages (see 8.3 (g) below).
- (i) Clinical evidence emphasises the health benefits associated with olive oil consumption, notably lower blood cholesterol content and reduced coronary disease.

- (j) The beneficial effects of the traditional Mediterranean diet are supported by a survey of 14 geographical regions in which the Mediterranean European countries and especially Crete had the lowest number of heart-related deaths per 10000 people over a 15 year period.
- (k) Taxonomic identification of Minoan fish remains confirms that their dietary contribution to a community was related to the local availability of species. It has been suggested that the DHA which can be supplied by fish is essential for the development of learning ability and visual acuity in infants.
- (l) Such clinical and X-ray investigations that have been undertaken on Minoan skeletal material do seem somewhat to belie the picture of a healthy island society and cannot be ignored in spite of the above deductions from art and archaeological material. In common with all early (and modern primitive) populations most Minoans appear to have died at about half the possible human life span, each illness or accident being potentially life threatening in the absence of sanitary practices and medication. Some fortunate individuals, however, lived longer. Their teeth seem to have given much trouble and were often lost early. In spite of women being supposedly important in the society they died younger than men, probably stressed by childbirth and a customary inferior diet to men. On the other hand they were, on average, no shorter than modern Cretans. Estimates based on increase in settlement numbers especially during the Early and Middle Minoan periods suggest that Crete supported the greatest population growth in the Aegean in the Bronze Age with achievements that have already been mentioned - although deficiency diseases have been detected especially in the very late period. Analysis of the skeletal material and manifold problems related to it, have been dealt with extensively in the text. Skeletal analyses are particularly handicapped by the paucity and capricious nature of the samples as well as by methodology and interpretation. It is very probable that living conditions varied greatly between the rural and the relatively wealthy and sophisticated urban areas and very much more work is required on skeletal material. As Dennell (1979 : 128) and McGeorge (1988 : 54) have suggested, isotopic bone analyses would throw a great deal of light on actual ratios of types of foods consumed during life.

### 8.3 Nutritional and biochemical conclusions.

- (a) Consumption of cereals on Crete in 1948 broadly conformed to criteria for the Mediterranean diet. More than 50% of cereals eaten were in the form of bread made of wheat, barley or a mixture of both with a suggested *per capita* consumption of 2,5 kg per week. Chemical analyses for whole wheat and wheat flour yielded carbohydrate contents of 58% and 68% respectively with corresponding protein levels of 11% and 14% (g/100g dry basis). For barley the figures are 57% and 62% for carbohydrate and 10% and 11% for protein. Cereals which comprised 30% by weight of the Cretan diet provided some 40% of calories which together with vegetables and legumes ensured that carbohydrates accounted for an excess of 50% of the calorie intake.

- (b) Chemical analyses of Cretan and Greek olive oil samples for lipid content and composition confirm that oil produced in eastern Crete was an important source of the mono-unsaturated oleic acid and the nutritionally essential *n*-6 (linoleic) acid. Cretan olive oil has a higher linoleic acid content than many other olive oils. These important fatty acids were clinically shown to lower total serum cholesterol. Analyses indicate that the linoleic acid content of the Cretan oil samples (9,4%) is higher than two of the Greek oils at 6,5% and 7,6%. (The provenance of the third Greek oil at 12,5% is unfortunately not known.) The amount of oleic and linoleic acid present in the Minoan diet naturally cannot be quantified, but the traditional consumption of olive oil on Crete is reportedly greater than for Greece as a whole and exceeds by 50% the intake of fats and oils in the United States of America.
- (c) Current clinical research indicates that there is an optimum dietary ratio between *n*-6 and *n*-3 essential fatty acids (particularly eicosapentaenoic and docosahexaenoic acids - EPA and DHA). The ratio consumed on Crete again cannot be quantified, but olives and even small quantities of fish would provide good sources of these respective nutrients.
- (d) Greek and Cretan olive oils contain a high level of the natural antioxidant  $\alpha$ -tocopherol (vitamin E). Analysis of oil from eastern Crete yielded an  $\alpha$ -tocopherol (vitamin E) level of 108 mg/kg. A level such as this would have ensured that Minoan olive oil had a satisfactory storage life and good organoleptic properties which would have enhanced its value as a Bronze Age trade commodity. The ratio of  $\alpha$ -tocopherol to polyunsaturated fats is the highest of all vegetable oils.
- (e) Analysis of Aegean fish for lipid content and composition undertaken in Cape Town, Herakleion and Thessaloniki, confirm the possibilities for the dietary contribution to Minoan Crete of the desirable *n*-3 fatty acids from the Aegean marine resource. Though the analytical techniques used by the three laboratories differed and disparities exist, squid, octopus, sole, mackerel and horse mackerel show good agreements for EPA contents. Similarly skipjack, sardine and octopus show good agreements for DHA content. The analyses indicate that the higher oil content fish, for example the Mediterranean sardine (*Sardinella aurita*) and the horse mackerel (*Trachurus trachurus*) have good levels of EPA. Conversely, the more muscular fish such as the tunas had good levels of DHA. Other fish identified archaeologically, including mullet, octopus and squid, also yielded satisfactory levels of DHA.
- (f) Research on infants, Rhesus monkeys, piglets and rats indicated that DHA deprivation leads to visual abnormalities and loss of visual and sensory perception with accompanying learning disabilities which are apparently irreversible. In poverty-stricken communities this has been shown to be associated with a lack of skills and innovation. Findings have been reinforced by socio-educational studies on economically deprived primary school children in Chile.

- (g) Computer analysis was used to estimate the contribution to Minoan diet of DHA and EPA obtained from Aegean fish. Taking the Mediterranean skipjack tuna (*Katsowumus pelamis*) as an example, it was calculated that a Cretan eating 168 grams of fish per week (Allbaugh 1953 : 110) would consume 10,94 grams of fish oil contributing 3,9 grams of DHA and 0,61 EPA, a combined total of 4,51 grams per week. This is the equivalent of 0,66 grams of DHA/EPA per day. Similar calculations show that consumption of the Mediterranean sardine (*Sardinella aurita*), mackerel (*Scomber japonicus*), horse mackerel (*Trachurus trachurus*) and mullet (*Mugil cephalus*) provide respective daily totals of 0,34, 0,14, 0,10 and 0,16 grams of DHA and EPA on an equivalent daily basis. Should fish consumption be increased to 400 grams *per capita* per week and again using skipjack as an example, a daily dietary intake of 1,62 grams of DHA and EPA could be achieved. This figure exceeds the current daily recommended nutritional requirement of 1 gram of these combined *n*-3 fatty acids. Leaf (1993 : 3) remarks that the *n*-3 fatty acids were present throughout the time our genes evolved and this may be why their effects are so ubiquitous, also affecting cell proliferation and the immune and inflammatory systems. He suggests that exciting findings could be forthcoming relating to the effects of the *n*-3 polyunsaturated fatty acids (PUFA) on cancer and auto-immune diseases.

### 8.3 Final Remarks

Perhaps one of the most disappointing aspects of Minoan studies is the failure, so far at any rate, of the deciphered Linear B script to reveal anything about its authors other than the records of accountants. Unlike the contemporary civilisations of the Near East and Egypt, they wrote nothing about themselves, their beliefs or their battles. They perceived no necessity to record earthly glory, preserve the body or the identity beyond the grave. When they finally did depict themselves late in their development, the frescoes of the rebuilt palaces largely concentrate on ritual or group activities that have no narrative component. Informed (and sometimes possibly subjective) speculation relating to the archaeological evidence over the years has offered theoretical evaluations of the Minoan economy, the religion, the technology, the skills, arts and crafts, demography and skeletal remains. All of these have been referred to in this thesis, together with the evidence from faunal and botanical remains, oceanography, analytical chemistry and computer analysis as well as medical and fishery sciences, in an attempt to provide another piece in the Cretan Bronze Age jig-saw puzzle - the possible role of the Mediterranean diet as a beneficial factor in the development of the Minoan civilisation.

## 9. BIBLIOGRAPHY

### 9.1 General Bibliography

Ackman RG

1988. Concerns for utilisation of marine lipids and oils. *Food Technology* 42 : 151-155.  
 1989. Nutritional composition of fats in seafoods. *Progress in Food and Nutrition Science* 13 : 161-241.

Allbaugh Leland G

1953. *Crete. A Case Study of an Undeveloped Area*. Princeton : Princeton University Press.

Ammerman AJ & Cavalli-Sforza L

1973. A population model for the diffusion of early farming in Europe. In: *The Explanation of Culture Change. Models in Prehistory*, ed Colin Renfrew. London : Duckworth, 343-357.  
 1984. *The Neolithic Transition and the Genetics of Population in Europe*. Princeton : Princeton University Press.

Angel JL

1967. Porotic hyperostosis or osteoporosis symmetrica. In: *Diseases in Antiquity: A survey of the diseases, injuries and surgery of early populations*, eds DR Brothwell & AT Sandison. Springfield, Illinois : CC Thomas, 378-389.  
 1971a. *Lerna II: The People*. American School of Classical Studies at Athens. Princeton : Princeton University Press.  
 1971b. Early Neolithic skeletons from Catal Hüyük: Demography and pathology. *Anatolian Studies* : 77-98.  
 1972. Ecology and population in the Eastern Mediterranean. *World Archaeology* 4 : 88-105.

Aravanis C, Mensink RP, Karalias N, Christodoulou B, Kafatos A & Katan MB

1988. Serum lipids, lipoproteins and nutrient intake in rural Cretan boys consuming high olive oil diets. *Journal Clinical Epidemiology* 41 : 1117-1123.

Arbuckle LD & Innis SM

1992. Docosahexaenoic acid in developing brain and retina of piglets fed high or low  $\alpha$ -linolenate formula with and without fish oil. *Lipids* 27(2) : 91-93.

Armelagos GJ, van Gerven DP, Martin DL & Huss-Ashmore R

1984. The effects of nutritional change in the skeletal biology of Northeast African (Sudanese Nubian) populations. In: *From Hunters to Farmers*, eds JD Clark & SA Brandt. Berkeley : University of California Press, 132-146.

Baggio GA, Pagnan M, Muraca S, Martini A, Opportuno A, Bonanome GB, Ambrosio S, Ferrari P, Guarini & Piccolo D

1988. Olive oil enriched diet: Effect on serum lipoprotein levels and biliary cholesterol saturation. *American Journal Clinical Nutrition* 47 (6) : 960-964.

Bailey G

1992. The palaeolithic of Klithi in its wider context. *Annual of the British School at Athens* 87 : 1-28.

Bang HO, Dyerberg J & Hjörne N

1976. The composition of food consumed by Greenland Eskimos. *Acta Medica Scandinavica* 200 : 69-73.

**Barker G**

1985. *Prehistoric Farming in Europe*. Cambridge : Cambridge University Press.

**Barlow SM & Pike IH**

1991. Humans, animals benefit from omega-3 polyunsaturated fatty acids. *Feedstuffs* 63(19) : 18-22.

**Baumbach L**

1977. The impact of the decipherment of the Linear B script on linguistic and historical studies. University of Cape Town. Inaugural Lecture No. 43.

**Becker MJ**

1975. Human skeletal remains from Kato Zakro. *American Journal of Archaeology* 79 : 271-276.

**Bennet J**

1990. Knossos in Context: Comparative Perspectives on the Linear B Administration of LM II-III Crete. *American Journal of Archaeology* 94 : 193-211.

**Benolken RM, Anderson RE & Wheeler TG**

1973. Membrane fatty acids associated with electrical response in visual excitation. *Science* 182 : 1253-1254.

**Bernal M**

1987, 1991. *Black Athena. The Afro-Asiatic Roots of Civilisation*. Vol. I and II. Rutgers University Press.

1990 Responses to critical reviews of Black Athena: The Afroasiatic Roots of Classical Civilization. Volume I : The Fabrication of Ancient Greece 1785-1985. *Journal of Mediterranean Archaeology* 3(1) : 111-137

**Berra B. & Rapelli S**

1986. Nutritional and biochemical aspects of olive oil. In: *World Conference on Emerging Technologies in the Fats and Oils Industry*. Proceedings of the American Oil Chemists Society, 1985, ed A Baldwin, 308-311.

**Betancourt PP**

1987. Dating the Aegean Late Bronze Age. *Archaeometry* 29 : 45-49.

**Betancourt PP & Davaras C**

1988. Excavations at Pseira, 1985 and 1986. *Hesperia* 57(3) : 208-225.

**Betancourt PP & Hope Simpson R**

1992. The agricultural system of Bronze Age Pseira. *Cretan Studies* 3 : 47-54.

**Bietak M**

1995a. Connections between Egypt and the Minoan World: New results from Tell el-Dab'a/Avaris. In: *Egypt, the Aegean and the Levant*, eds W Vivian Davies & L Schofield. London : British Museum Press, 19-28.

1995b. *Avaris, Capital of the Hyksos: Recent Excavations at Tell el-Dab'a*. London : British Museum Press.

**Bintliff JL**

1977a. *Natural environment and human settlement in prehistoric Greece*. British Archaeological Reports Suppl. Series 28, Oxford.

1977a. *Natural environment and human settlement in prehistoric Greece: Part II*. Oxford : British Archaeological Reports, Supplementary Series, 28(ii) : 632.

- 1977b. Pedology and land use. *Annual of the British School at Athens* 72 : 24-30.  
 1984. Structuralism and myth in Minoan studies. *Antiquity* LVIII : 33-38.

**Black A & C**

1987. *Black's Medical Dictionary*. London.

**Blackman DJ & Branigan K**

1975. An archaeological survey of the south coast of Crete between the Ayiofarango and Christostomos. *Annual of the British School at Athens* 70 : 17-36.  
 1977. An archaeological survey of the lower catchment of the Ayiofarango valley. *Annual of the British School at Athens* 72 : 13-84.

**Bloch ME**

1793. Part 7 of *Naturgeschichte der ausländischen Fische* : 361-396. Berlin : 1785-95.

**Boardman J**

1967. *Pre-classical from Crete to Archaic Greece*. London : Penguin Books.  
 1980. *The Greeks Overseas*. London : Thames & Hudson.

**Bosanquet RC**

1902. Excavations at Palaikastro I. *Annual of the British School at Athens* 8 : 306-316.

**Bosanquet RC & Dawkins RM**

1923. *The Unpublished objects from the Palaikastro Excavations 1902-1906*. London : British School at Athens.

**Boserup E**

1965. *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. London : Allen & Unwin.

**Bower D**

1972. Chromatography analyses for lipids in clay. In: *Myrtos: An Early Bronze Age Settlement in Crete*. London : Thames & Hudson, 330-331.

**Boyd H & Dawkins RM**

1900. *Journal of the British School at Athens* : 150-155 (cited Glotz 1925, no title given).

**Boyd Hawes Harriet**

1908. *Gournia, Vasiliki and other Prehistoric sites on the Isthmus of Hierapetra*. Philadelphia : Exploration Society Free Museum of Science and Art.

**Branigan K**

1970. *The Foundations of Palatial Crete*. London : Routledge & Kegan Paul.  
 1972. Minoan settlements in east Crete. In: *Man, Settlement and Urbanism*, eds P Ucko, R Tringham & CW Dibleby. London : Duckworth, 751-759.  
 1973. Crete, the Levant and Egypt in the Early Second Millennium BC. In: *Proceedings of the Third Cretological Congress, Athens 1971*, 22-27.  
 1974. *Aegean Metalwork of the Early and Middle Bronze Age*. Oxford University Press.  
 1987. The economic role of the first palaces. In: *The Function of Minoan Palaces*, eds R Hagg & N Marinatos. Proceedings of the 4th International Symposium at the Swedish Institute at Athens. Stockholm : Paul Astroms Forlag, 245-249.  
 1993-94. Crete: Ziros. *Annual Report of the Managing Committee for the Season 1993-1994*. The British School at Athens, 26.

Braun T

1991. Ancient Mediterranean food. In: *The Mediterranean Diets in Health and Disease*, ed Gene A Spiller. New York : Van Nostrand Reinhold, 10-58.

Bronte-Stewart BA, Antonis A, Eales L & Brock JF

1956. Effects of feeding different fats on serum cholesterol levels. *Lancet* i : 521-530.

Broodbank C & Strasser TF

1991. Migrant farmers and the Neolithic colonisation of Crete. *Antiquity* 65 : 233-243.

Brothwell DR & Sandison AT (eds)

1967. *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Populations*. Springfield, Illinois : CC Thomas.

Bruce-Chwatt LJ & de Zulueta J

1980. *The Rise and Fall of Malaria in Europe: A Historico-epidemiological Study*. Oxford : Oxford University Press.

Bulgan M

1957. Fluctuations of salinity in the Adriatic. *Izv. Inst. Oceanogr. Ribarst* 2(2) : 3-62.

Burr ML

1989. Fish and the cardiovascular system. *Progress in Food and Nutrition Science* 13 : 291-316.

Burr ML, Gilbert JF, Holliday, RM, Elwood PC, Fehily AM, Rogers S, Sweetnam PM & Deadman NM

1989. Effects of changes in fat, fish and fibre intakes on death and myocardial infarction: Diet and reinfarction trial. *Lancet* ii : 757-761.

Burr ML, Sweetnam PM & Fehily AM

1994. Diet and reinfarction. Letter to the Editor. *European Heart Journal* 15 : 1152.

Cann JR & Renfrew Colin

1964. The characterisation of obsidian and its application to the Mediterranean region. *Proceedings of the Prehistoric Society* 30 : 111-133.

Cartledge P

1979. *Sparta and Lakonia*. London : Routledge & Kegan Paul.

Carpenter AP

1979. Determination of tocopherols in vegetable oils. *Journal of the American Chemists Society* 56 : 668-671

Castelden R

1990. *Minoans: Life in Bronze Age Crete*. London : Routledge.

Chadwick John

1972. The Mycenaean Documents. In: *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Environment*, eds WA McDonald & GR Rapp. Minneapolis : University of Minnesota Press, 110-116.

1976. *The Mycenaean World*. Cambridge : Cambridge University Press.

Charles JA

1972. Physical science and archaeology. *Antiquity* XLVI, 182 : 134-139.

## Cherry JF

1981. Pattern and process in the earliest colonisation of the Mediterranean islands. *Proceedings of the Prehistoric Society* 47 : 41-68.
1982. A preliminary definition of site distribution on Melos. In: *An Island Polity*, eds C Renfrew & M Wagstaff. Cambridge : Cambridge University Press, 10-23.
1983. Evolution, revolution and the origins of complex society in Minoan Crete. In: *Minoan Society*, eds O Krzyszkowska & L Nixon. Bristol : Bristol Classical Press, 323-345.
1990. The first colonisation of the Mediterranean islands: A review of recent research. *Journal of Mediterranean Archaeology* 3/2 : 145-221.

## Childe V Gordon

1942. *What happened in history*. London : Penguin.

## Chrysoulaki S &amp; Platon L

1987. Relations between the Town and Palace of Zakros. In: *The Function of Minoan Palaces*, eds R Hagg & N Marinatos. Proceedings of the 4th International Symposium at the Swedish Institute at Athens. Stockholm : Paul Astroms Forlag, 77-84.

## Cimato A

1990. Effect of agronomic factors on virgin olive oil quality. *Olivae* 31(4) : 20-31.

## Clark JD &amp; Brandt SA (eds)

1984. *From Hunters to Farmers*. Berkeley : University of California.

## Clarke JP, Hunsicker JC &amp; Megremis CJ

1990. Tocopherols: nature's antioxidant. *Food Australia* 42(5) : 262-263.

## Cominacini L, Garbin U, Davoli A, Cenci B &amp; Bosello O

1991. Lipids. In: *The Mediterranean Diets in Health and Disease*, ed Gene A Spiller. New York : Van Nostrand Reinhold, 195-218.

## Connor WE &amp; Neuringer M

1988. The effect of *n*-3 fatty acid deficiency and repletion on the fatty acid composition and function of the brain and retina. In: *Biological Membranes: Aberrations in Membrane Structure and Function*, eds M Kornowsky, A Leaf & C Bolis. New York : Allan R. Liss Inc, 275-294.

## Corondialis A, Ioannidis J &amp; Aravanis C

1980. Diet changes in rural Crete between 1960 and 1980. *Cited Pique GC*. 1988.

## Crawford MA, Hassan AG, Williams G &amp; Whitehouse WL

1976. Essential fatty acids and foetal brain growth. *Lancet* i : 452-453.

## Cresta M, Ledermann S, Garnier A, Lombardo E &amp; Lacowly G

1969. Etude des consommations alimentaires des populations de onze régions de la communauté européenne en vue de la détermination des niveaux de contamination radioactive. Rapport établi au Centre d'Etude Nucléaire de Fatenay-aux-Roses, France: EURATOM, Commissariat à l'énergie atomique (CEA).

## Crossland RA &amp; Birchall A (eds)

1973. *Bronze Age Migrations in the Aegean*. *Archaeological and Linguistic Problems in Greek Prehistory*. London : Duckworth.

## Cullen T

1995. Mesolithic mortuary ritual at Franchthi Cave, Greece. *Antiquity* 96 : 270-289.

**Davaras C**

1971. Early Minoan cemetery at Agia Photia, Siteia. *Athens Annals of Archaeology* : 392-397.  
 1975. Early Minoan jewellery from Mochlos. *Annual of the British School at Athens* 70 : 101-114.  
 1994. Hagios Nikolaos. Brief illustrated archaeological guide. Athens : Editions Hannibal.

**Davis J**

1973. *Land and Family at Pisticci*. London : Athlone Press.

**Dawkins RM**

- 1902-1903. Palaikastro II. *Annual of the British School at Athens* 9 : 295ff.  
 1904-1905. Excavations at Palaikastro IV. *Annual of the British School at Athens* 11 : 258-308.

**Dawson WB**

1967. The Egyptian Medical Papyri. In: *Diseases in Antiquity: A Survey of the Diseases, Injuries and Surgery of Early Populations*, eds DR Brothwell & AT Sandison. Springfield, Illinois : CC Thomas, 110ff.

**De Koning AJ, Evans AA, Heydenrych C, Purcell C de V & Wessels, JPH**

1983. A critical investigation of a number of different methods of lipid determination in fish meal, with particular emphasis on corrections required in these determinations. *Journal of the Science of Food and Agriculture* 36 : 180.

**De Koning AJ**

1993. Report on the First Congress of the International Society for the Study of Fatty Acids and Lipids, Lugano, Switzerland. Memorandum No. 385. Fishing Industry Research Institute, Cape Town.  
 1994. The relationship between the refractive index of fish oils and their content of eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and total polyunsaturated fatty acids (PUFA). *Fat Science Technology* 96(9) : 352-356.

**De Lorgeril M, Renaud S, Mamelle N, Salen P, Martin J-L, Monjaud I, Guidollet J, Touboul P & Delaye J**

1994. Mediterranean alpha-linolenic acid-rich in secondary prevention of coronary heart disease. *Lancet* 343: 1454-1459.

**Dennell Robin**

1979. Prehistoric diet and nutrition: Food for thought. *World Archaeology* 11(2) : 121-135.  
 1983. *European Economic Prehistory: A New Approach*. London : Academic Press.

**Department of Health and Social Subjects, United Kingdom**

1994. Nutritional aspects of cardiovascular disease. *Report No. 46 of the Cardiovascular Review Group Committee on Medical Aspects of Food Policy*. London : Her Majesty's Stationery Office.

**Dickinson OTPK**

1994. *The Aegean Bronze Age*. Cambridge : Cambridge University Press.

**Diem K & Lenter C (eds)**

1970. *Scientific Tables*, 7th Edition. Basle : Geigy Pharmaceutical Company.

**Dolukhanov PM**

1973. The Neolithization of Europe: A chronological and ecological approach. In: *The Explanation of Culture Change. Models in Prehistory*, ed Colin Renfrew. London : Duckworth, 329-342.

Doren D McNeill

1994. *Winds of Crete*. Athens : Efstathiadis Group reprint.

Doumas Christos

1980. *Santorini. A Guide to the Island and its Archaeological Treasures*. Athens : Ekdotike Athenon.

Duthie IF & Barlow SM

1992. Dietary lipids exemplified by fish oils and their *n*-3 fatty acids. In: Proceedings of the 1990 International Food Science and Technology Symposium, Glasgow. *Food Science and Technology Today* 6(1) : 20-36.

Dyerberg J, Bang HO & Hjørne H

1975. Fatty acid composition of the plasma lipids in Greenland Eskimos. *American Journal of Clinical Nutrition* 28 : 958-966.

Eaton SB & Konnor M

1985. Palaeolithic nutrition: A consideration of its nature and current implications. *New England Journal of Medicine* 312 : 283-289.

Edwards IES

1969. Introductory guide to the Egyptian collections in the British Museum. The Trustees of the British Museum, London.

Ehnholm C, Huttunen JK & Pietinen P

1982. Effect of diet on serum lipoprotein in a population with a high risk of coronary heart disease. *New England Journal of Medicine* 307 : 850-855.

Enslin M, Milon H & Malnoë A

1991. Effect of low intake of *n*-3 fatty acids during development of brain phospholipid fatty acid composition and exploratory behaviour in rats. *Lipids* 26(3) : 203-207.

Evans A J

1921-1936. *The Palace of Minos at Knossos*. London : MacMillan.

Evans JD

1964. Excavations in the Neolithic settlement at Knossos, 1957-60. Part I. *Annual of the British School at Athens* 59 : 132-240.

1968. Knossos Neolithic Part II. *Annual of the British School at Athens* 63 : 239-276.

1971. Neolithic Knossos: The Growth of a Settlement. *Proceedings of the Prehistoric Society* 37 : 95-117.

Evans JD & Renfrew Colin

1968. *Excavations at Saliagos near Antiparos*. British School of Archaeology Supplementary Volume No. 5. London : Thames & Hudson.

Faber GL

1883. *The Fisheries of the Adriatic and the Fish Thereof*. London : Bernard Quaritch.

FAO (Food & Agriculture Organisation of the United Nations)

1984. Food Balance Sheets 1979-1981 Average. Rome : FAO.

Fedeli E & Testolin G

1991. Edible fats and oils. In: *The Mediterranean diets in health and disease*, ed Gene A Spiller. New York : Avi Books Van Nostrand Reinhold, 125-134.

Ferro-Luzzi A & Sette S

1989. The Mediterranean diet: An attempt to define its present and past composition. *European Journal of Clinical Nutrition* 43 (Suppl. 2) : 13-29.

Fidanza F & Versiglioni N

1987. *Tabella di Composizione Degli Alimenti Idelson*. Naples : Idelson.

Floyd C, Onyshkevych L, Beaudoin J & Mitrakis G

1995. Excavations at Pseira 1993-1994. Abstract of paper. 96th Annual General Meeting Archaeological Institute of Americas. *American Journal of Archaeology* 99 : 313.

Fogerty AC

1989. Dietary fatty acids and blood lipids. *Food Research Quarterly* 49(3&4) : 36-44.

Forsdyke EJ

1956. *Greece before Homer*. London: Parrish.

Foxhall L & Forbes HA

1982. The role of grain as a staple food in Classical Antiquity. *Chiron* xii : 41-90.

Gale N

1990. The provenance of metals for Early Bronze Age Crete - local or Cycladic. *Pepragmena I* : 299-316.

Gallant TW

1985. *A Fisherman's Tale*. Gent: Belgian Archaeological Mission in Greece in collaboration with the Seminar for Greek Archaeology of the State University of Gent.

1991. *Risk and Survival in Ancient Greece*. Cambridge : Polity Press.

Gamble G

1981. Social control and the economy. In: *Economic Archaeology*, eds A Sheridan & G Bailey. Oxford : British Archaeological Reports 96 : 215-29.

Gejvall Nils-Gustaf

1969. *Lerna. A Pre-classical Site in the Argolid*. Volume I: *The Fauna*. American School of Classical Studies at Athens. Princeton University Press.

Gennett J.

1982. Three Holocene pollen records from southern Greece. *Palynology* 6 : 282.

Gesell GC, Preston Day L & Coulson WDE

1988. Excavations at Kavousi, Crete, 1987. *Hesperia* 57(4) : 279-301.

Giacco R & Riccardi G

1991. Comparison of current eating habits in various Mediterranean countries. In: *The Mediterranean Diets in Health and Disease*, ed Gene A Spiller. New York : Van Nostrand Reinhold, 3-9.

Gilat E, Kane JE & Martin JC

1965. Study of an ecosystem in the coastal waters of the Ligurian Sea. *Surface Zooplankton Bulletin Institute Oceanography, Monaco*, 65 : 1353.

Ginsberg HN, Barr SL, Gilbert A, Karmally W, Deckelbaum R, Kaplan K, Ramakrishnan R, Holleran S & Dell RB

1990. Reduction of plasma cholesterol levels in normal men on an American Heart Association Step I diet or a Step I diet with added monounsaturated fat. *New England Journal Medicine* 322 (9) : 574-579.

Glutz G

1925. *The Aegean Civilisation*. London : Kegan Paul, Trench, Trubner & Co. Ltd.

Gracian Tous J

1966. El aceite de oliva frente a otros aceites comestibles dessemillas. *Grassas y aceites* 17 : 100-102.

Graham JW

1962. *The Palaces of Crete*. Princeton : Princeton University Press.

1968. The Cretan palace: Sixty-seven years of exploration. In: *A Land Called Crete. A Symposium in Memory of Harriet Boyd Hawes*. Northampton Massachusetts : Smith College Studies in History, 45.

Grundy SM

1986. Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. *New England Journal Medicine* 314 (12) : 745-748.

Gulland, JA

1971. *The Fish Resources of the Ocean*. Surrey : Fishing News Books Ltd (UN FAO).

Gussow JD

1995. Mediterranean diets: Are they environmentally responsible? *Journal of Clinical Nutrition* 61 (Supplement) : 1383S-1389S.

Hagg R & Marinatos N (eds)

1987. *The Function of Minoan Palaces*. Proceedings of the 4th International Symposium at the Swedish Institute at Athens. Stockholm : Paul Astroms Forlag.

Haggis DC

1996. Excavations at Kalo Khorio, East Crete. *American Journal of Archaeology* 100 : 645-681.

Haley JB & Blegen CW

1928. The coming of the Greeks. *American Journal of Archaeology* 32 : 141.

Halstead Paul

1977. The Bronze Age demography of Crete and Greece - A Note. *Annual of the British School at Athens* 72 : 107-111.

1981a. From determinism to uncertainty: Social storage and the rise of the Minoan Palace. In: *Economic Archaeology: Towards an Integration of Ecological and Social Approaches*, eds AS Sheridan & G Bailey. Oxford: British Archaeological Reports International Series 96 : 187-213.

1981b. Counting sheep in Neolithic and Bronze Age Greece. In: *Pattern of the Past*, eds I Hodder, G Isaac & N Hammond. Cambridge : Cambridge University Press, 307-339.

1987a. Traditional and ancient rural economy in Mediterranean Europe: Plus ça change? *Journal of Hellenic Studies* cvii : 77-87.

1987b. Man and other animals in later Greek prehistory. *Annual of the British School at Athens* 82 : 71-83

1992. Agriculture in the Bronze Age Aegean: Towards a model of palatial economy. In: *Agriculture in Ancient Greece*. Acta instituti Atheniensis Regni Suecae, Series in 4°, XLII. Proceedings of

the 7th International Symposium at the Swedish Institute at Athens, 16-17 May 1990, ed Berit Wells, Stockholm, 105-113.

#### Hansen J M

1988. Agriculture in the Prehistoric Aegean: Data versus speculation. *American Journal of Archaeology* 92 : 39-52.
1991. *The Palaeoethnobotany of Franchthi Cave*. Bloomington, Indiana : Indiana University Press. Excavations at Franchthi Cave, Greece, 7.

#### Harper V, MacInnes R, Campbell D and Hall M

1991. Increased birth weight in northerly islands: Is fish consumption a red herring. *British Medical Journal* 303 : 166.

#### Harris WS

1996. n-3 Fatty acids and lipoproteins: Comparison of results from human and animal studies. *Lipids* 31(3) : 243-252.

#### Hassan Fekri A

1981. *Demographic Archaeology*. New York : Academic Press.
1984. Environment and subsistence in Predynastic Egypt. In: *From Hunters to Farmers*, eds JD Clark & SA Brandt. Berkeley: University of California Press, 57-64.
1988. The Predynastic of Egypt. *Journal of World Prehistory* 2 : 135-185.

#### Hayden BJ, Moody JA & Rackham D

1992. The Vrokaastro survey project, 1986-1989. Research design and preliminary results. *Hesperia* 61 : 293-353.

#### Higgins R

1967. *Minoan and Mycenaean Art*. London : Thames & Hudson.

#### Hinz G

1979. Neue Tierknochenfunde aus der Magula Pevkakia in Thessalien. I. Die Nichtwieder Käner. Dissertationen München Institut für Palaeoantomie.

#### Hirai A, Terano T, Saito H, Tamura Y & Yoshida S

1987. Clinical and epidemiological studies of eicosapentaenoic acid in Japan. In: *Proceedings of the AOAC Short Course on Polyunsaturated Fatty Acids and Eicosanoids*, ed WEM Lands. Champaign, Illinois : American Oil Chemists' Society, 9-24.

#### Hodder I, Isaac G & Hammond N (eds)

1981. *Pattern of the past: Studies in Honour of David L Clarke*. Cambridge : Cambridge University Press.

#### Hodder I

1982. The identification and interpretation of ranking in prehistory: A contextual perspective. In: *Ranking, Resource and Exchange*, eds Renfrew C & Shennan S. Cambridge : Cambridge University Press, 150-154.

#### Hood MSF, Warren P & Cadogan G

1964. Travels in Crete, 1962. *Annual of the British School at Athens* 59 : 50-99.

#### Hood Sinclair

1971. *The Minoans. Crete in the Bronze Age*. London : Thames & Hudson.

**Hope Simpson R**

1983. Review: Lasithi. A history of settlement on a highland plain in Crete. *Hesperia Supplement* 18. American School of Classical Studies at Athens. Princeton, New Jersey. *American Journal of Archaeology* 87 : 404-405.

**Hope Simpson R & Betancourt PP**

1990. Intensive survey of Pseira island. *American Journal of Archaeology* 94 : 322-323.

**Hopf M**

1961. Pflanzenfunde aus Lerna Argolis. *Der Züchter* 31 : 239-247.

**Hopper RJ**

1979. *Trade and Industry in Classical Greece*. London : Thames & Hudson.

**Hutchinson RW**

1962. *Prehistoric Crete*. London : Penguin Books.

**Immerwahr S**

1983. The people in the frescoes. In: *Minoan Society*, eds O Krzyszkowska & L Nixon. Bristol: Bristol Classical Press, 143-153.

**Interesse FS, Ruggiero P & Vitagliano M**

1971. L'autossidazione dell'olio di oliva influenza dei pigmenti clorofillici. *Industria Agraria* 9 : 318-324.

**Jacobsen TW**

1969. Explorations at Porto Cheli and vicinity; Preliminary Report II. The Franchthi Cave 1967-1968. *Hesperia* 38 : 345-381.

1976. 17,000 years of Greek Prehistory. *Scientific American* 234 : 76-87.

1981. Franchthi cave and the beginning of settled village life in Greece. *Hesperia* 50 : 303-319.

**Jamieson EC, Abbasi KA, Cockburn F, Farquharson J, Logan RW & Patrick WA**

1993. *The effect of diet in term infant cerebral cortex fatty acid composition*. Paper delivered at 1st International Congress of the International Society for the Study of Fatty Acids and Lipids, Lugano, Switzerland, 30 June-3 July 1993.

**Jameson MH, Runnels CN & van Andel TH**

1994. *A Greek Countryside: The Southern Argolid from Prehistory to the Present Day*. Stanford, California : Stanford University Press.

**Jarman MR, Bailey GN & Jarman HN**

1982. *Early European Agriculture: Its Foundation and Development*. Cambridge : Cambridge University Press.

**Johnstone P**

1980. *The Sea-craft of Prehistory*. London : Routledge & Kegan Paul.

**Jones GEM, Wardle K, Halstead P & Wardle D**

1986. Crop storage at Assiros. *Scientific American* 254 : 94-91.

**Kafatos A, Kouroumalis, Vlachonikolis D, Theodorou C, & Labadarios D**

1991. Coronary heart disease risk factor status of the Cretan urban population in the 1980's. *American Journal of Clinical Nutrition* 54 : 591-598.

## Kanta A

1983. Minoan and Traditional Crete: Some parallels between two cultures in the same environment. In: *Minoan Society*, eds O Kryzyszkowska & L Nixon. Bristol : Bristol Classical Press. 155-162.

## Kates M

1972. *Techniques of Lipidology: Isolation, Analysis and Identification of Lipids*. New York : North Holland Publishing Company.

## Karakoltsidis P, Zotos A, &amp; Constantinides SM

1995. Composition of the commercially important Mediterranean finfish, crustaceans and molluscs. *Journal of Food Composition and Analysis* 8 : 258-273.

## Kenna VEG

1960. *Cretean Seals*. Oxford : Oxford University Press.

## Keys A.

1970. Coronary heart disease in seven countries. *Circulation* 41(1) : 1-211.  
 1980. *Seven Countries: A Multivariate Analysis of Death and Coronary Heart Disease*. Cambridge, Mass : Harvard University Press.  
 1997. The Man behind the Mediterranean diet. Verbatim interview in article by P Jaret in *Eating Well* magazine, March/April issue.

## Keys A, Anderson JT &amp; Grande F

1957. Prediction of serum-cholesterol response of man to changes of fats in the diet. *Lancet* ii : 959-966.  
 1965. Serum cholesterol response to changes in the diet. *Metabolism* 14 : 747-787.

## Keys A &amp; Keys M

1975. *How to Eat Well and Stay Well the Mediterranean Way*. New York. : Doubleday.

## Keys A, Menotti A, Karvonen MJ, Aranis C, Blackburn H, Buzina R, Djordjevic BS, Dontas AS, Fidanza MH, Keys D, Kromhout S, Nedeljkovic S, Punsar F, Simic BS &amp; Toshima H

1986. The diet and 15 year death rate in Seven Countries Study. *American Journal of Epidemiology* 124 : 903-915.

## Killen JT

1964. The wool industry of Crete in the Late Bronze Age. *Annual of the British School at Athens* 59 : 1-15.

## Kinsella JE

1990. Possible mechanisms underlying the effects of dietary n-3 polyunsaturated fatty acids. *Omega-3 News* V(1) : 1-4.

## Kiritsakis A &amp; Dugan LR

1985. Studies in photo-oxidation of olive oils. *Journal American Oil Chemists Society* 62 : 892-896.

## Kiritsakis A &amp; Markakis P

1987. Olive oil : A Review. *Advances in Food Research* 31 : 453-482.

## Kopaka Katérina &amp; Platon Leftéris

1993. Installations Minoennes de traitement des produits liquides. *Bulletin de Correspondence Hellénique* 117 : 35-101.

Kromann N & Green A

1980. Epidemiological studies in the Upernavik district Greenland. Incidence of some chronic diseases 1950-1974. *Acta Medica Scandinavica* 208 : 401-406.

Kromhout Daan, Bosschieter Edward B & Coulander Cor de Lezenne

1985. The inverse relation between fish consumption and 20-year mortality from coronary heart disease. *New England Journal of Medicine* 312 : 1206-1209.

Laevastu T & Rosa H

1963. Distribution and relative abundance of tunas in relation to their environment. Proceedings of the World Scientific Meeting on the Biology of Tunas and Related Species, La Jolla, California. Fisheries Report No. 6.3. Experimental Paper 47 : 1835-1851.

Leaf A & Weber PC

1988. Cardiovascular effects of *n*-3 fatty acids. *New England Journal of Medicine* 318 (9) : 519-557.

Leaf A

1993. Omega-3 PUFA an update: 1986-1993. *Omega-3 News* 8(1) : 1-4.

Lefkowitz M

1996. *Not Out of Africa: How Afrocentrism Became an Excuse to Teach Myth as History*. New York : Basic Books, Harper Collins Inc.

Lefkowitz M & Maclean Rogers G (eds)

1996. *Black Athena Revisited*. Chapel Hill and London : University of North Carolina Press.

Lintas C & Mariani-Constantini A

1991. Cereal Foods: Wheat, corn, rice, barley and other cereals and their products. In: *The Mediterranean Diets in Health and Disease*, ed Gene A Spiller. New York : Van Nostrand Reinhold, 59-101.

MacGillivray JA & Sackett LH

1984. An archaeological survey of the Roussolakkos area and Palaikastro. *Annual of the British School at Athens* 79 : 29-159.

MacGillivray JA, Sackett LH, Driessen JM & Hemingway S

1992. Excavations at Palaikastro, 1991. *Annual of the British School at Athens* 87 : 121-152.

Manning SW

1990. The Thera Eruption: The Third Congress and the problem of the date. *Archaeometry* 32 : 91-100.

Manoukas AG & Hasapidou MN

1989. Actes du Congrès international "Chevreul" pour L'etude des corps gras Premie Congrès Eurolipid: Angers 6-9 Juin 1989. Organisé par l'Association Française pour l'Etude des Corps Gras, 604-607.

Marinatos S & Hirmer M

1960. *Crete and Mycenae*. London : Thames and Hudson.

Mattison FH & Grundy SM

1985. Comparison of effects of dietary saturated, monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *Journal Lipid Research* 26 : 194-202.

McDonald WA & Hope Simpson R

1972. Archaeological exploration. In: *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Environment*, eds WA McDonald & GR Rapp. Minneapolis : University of Minnesota Press, 117-146.

McDonald WA & Rapp GR (eds)

1972a. *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Environment*. Minneapolis : University of Minnesota Press.

McDonald WA & Rapp GR

1972b. Perspectives. In: *The Minnesota Messenia Expedition: Reconstructing a Bronze Age Environment*, eds McDonald WA & Rapp GR. Minneapolis : University of Minnesota Press, 240-261.

McGeorge PJP

1988. Health and diet in Minoan times. In: *New aspects of Archaeological Science in Greece*, eds RE Jones & HW Catling. Occasional paper of the Fitch Laboratory, British School at Athens : 47-54.

1990. A comparative study of the mean life expectation of the Minoans. *Proceedings of the 6th Cretological Congress*, 419-428.

McLaughlin PJ & Wihrauch JL

1979. Vitamin E contents of foods. *Journal of the American Dieticians Association* 75 : 647-665.

McNeal RA

1972. The Greeks in history and prehistory. *Antiquity* XLVI, 181 : 19-28.

Meiklejohn C & Zvelebil M

1991. Health status of European populations at the agricultural transition and the implications for the adoption of farming. In: *Health in Past Societies: Biocultural Interpretations of Human Skeletal Remains in Archaeological Context*, eds Helen Bush & Marek Zvelebil. Oxford Tempus Reparatum, British Archaeological Reports International Series 567 : 129-135.

Melena JL

1983. Olive oil and other sorts of oil in the Mycenaean tablets. *Minos* 18 : 89-123.

Menotti A

1991. Cardiovascular diseases. In: *The Mediterranean Diet in Health and Disease*, ed GA Spiller. New York : Avi Books Van Nostrand Reinhold, 232-251.

Mensink KP & Katan MB

1987. Effect of monounsaturated fatty acids versus complex carbohydrates on high density lipoproteins in healthy men and women. *Lancet* 1(8525) : 122-125.

1989. Effect of diet enriched with mono-unsaturated fatty acids on levels of low-density and high-density lipoprotein cholesterol in healthy women and men. *New England Journal of Medicine* 321(7) : 436-441.

Michell H

1957. *The Economics of Ancient Greece*. Cambridge : Heffer & Sons.

Molteno CJ & Riley FR

1986. *The Tuna and Billfishes of Southern Africa*. Cape Town : Fishing Industry Research Institute.

**Monckeberg F**

1991. Chilean Nutrition Intervention Programme. Unpublished paper delivered to the South African Medical Research Council, Parow, South Africa, November 1991. Based on the work of Vial *et al (qv)*.

**Montedoro G & Garofolo L**

1984. Qualitative characteristics of Virgin Olive Oils. The influence of variables such as variety, environment, preservation, extraction, conditioning of the finished product. *La Rivista Italiana delle Sostanze Grasse* 61(3) : 154-168.

**Moody J**

1987. The Environmental and Cultural Prehistory of the Khania Region of West Crete : Neolithic through Late Minoan III. Unpublished Ph.D. Thesis, University of Minnesota.

**Morgan L**

1995. Minoan painting and Egypt: The case of Tell el-Dab'a. In: *Egypt, the Aegean and the Levant*, eds W Vivian Davies & L Schofield. London : British Museum Press, 29-53.

**Morrison WR & Smith LM**

1964. Preparation of fatty acid methyl esters and dimethyl acetals from lipids with boron trifluoride. *Journal of Lipid Research* 5 : 600-609.

**Mountjoy PA**

1984. The Marine style pottery of LMIB/LHIIA : Towards a corpus. *Annual of the British School at Athens* 79 : 161-219.

**Muhly JD**

1990. Black Athena versus traditional scholarship. *Journal of Mediterranean Studies* 3 : 87-110.

**Musgrave JH, Neave RAH, Prag AJNW, Sakellarakis E & Sakellarakis JA**

1994. The priest and priestess from Archanes-Anemospilia: Reconstructing Minoan faces. *Annual of the British School at Athens* 89 : 89-100.

**Mylona Dimitra**

1994. *Fish Remains from Excavations at Palaikastro, Crete*. Unpublished manuscript.

**Nelson AM**

1972. Diet therapy in coronary disease: Effects on mortality of high protein, high seafood, fat controlled diet. *Geriatrics* 27 : 103-116.

**Nestel PJ**

1987. Fish oil fatty acids - the answer to heart disease. *CSIRO Food Research* 47 : 9-12.

**Neuringer M, Anderson G J & Connor WE**

1988. The essentiality of *n*-3 fatty acids for the development and function of the retina and brain. *Annual Review Nutrition* 8 : 517-541.

**Neuringer M & Connor WE**

1989. Omega-3 fatty acids in the retina. In: *Dietary n-3 and n-6 Fatty Acids: Biological Effects and Nutritional Essentiality*, eds Claudio Galli and Artemis P. Simopoulis. New York : Plenum Press.

**Newberry PE & Griffith FU**

1893. *Beni Hassan, I-IV*. London : Egypt Exploration Fund.

Olsen SF, Grandjean P, Weihe P and Viderø T.

1993. Frequency of seafood intake in pregnancy as a determinant of birth weight. Evidence for a dose dependent relationship. *Journal of Epidemiology and Community Health* 47 : 436-440.

Palmer LR

1963. *The Interpretation of Mycenaean Greek Texts*. Oxford : Clarendon Press.

Palmer Ruth

1989. Subsistence rations at Pylos and Knossos. *Minos* XXIV : 89-125.

Panagiotaki Marina

1993. The temple repositories of Knossos. New information from the unpublished notes of Sir Arthur Evans. *Annual of the British School at Athens* 88 : 49-91.

Peatfield A & Morris C

1995. Report on the 1995 study season from the Atsipades Korakias Peak Sanctuary. *Annual Report of the Managing Committee, British School at Athens, 1994-1995*.

Peifer JJ

1967. Hypercholesterolemic effects of marine oils. In: *Fish Oils*, ed Maurice E. Stansby. Westport, Connecticut : Avi Publishing Co., 322-361.

Pendlebury JDS, Eccles E & Money-Coutts MB

1934. Travels in Crete. *Annual of the British School at Athens* 33 : 80-100.

Pendlebury JDS

1930. *Aegyptiaca, a Catalogue of Egyptian Objects in the Aegean Area*. Cambridge : Cambridge University Press.

1939. *The Archaeology of Crete*. London : Methuen.

Pendlebury HW, Pendlebury JDS & Money-Coutts MB

1936. Excavations in the Plain of Lasithi I: The Cave of Trapeza. *Annual of the British School at Athens* 36 : 5.

Percival T

1783. Observations on the medicinal uses of the *oleum jeconis ascelli* or cod liver oil in the chronic rheumatism and other painful disorders. *London Medical Journal* 3(4) : 393-401.

Perlès C

1979. Des navigateurs mediterraneens il y a 10,000 ans. *La Recherche* 10(96) : 82-83.

Petersen RF

1965. *Wheat, Botany, Cultivation and Utilisation*. London : Leonard Hall Books.

Pique GC

1988. *Omega-3: The fish oil factor. Natural Food Sources and Health Effects*. San Diego, California : Omega-3 Projects Inc.

Platon Nicolas

1964. *PractArchEt*, 165-166 (no further details available) cited by Kopaka & Platon 1993 : 56.

1970. *Crete*. London : Barrie & Jenkins.

1971. *Zakros: The Discovery of a Lost Palace of Ancient Crete*. New York : Scribners.

## Poursat J-C

1987. Town and Palace at Malia in the protopalatial period. In: *The Function of Minoan Palaces*, eds R Hagg & N Marinatos. Proceedings of the 4th International Symposium at the Swedish Institute at Athens. Stockholm : Paul Astroms Forlag, 75-76.

## Powell Judith

1992. Archaeological and pictorial evidence for fishing in the Bronze Age: In: *Aegean Bronze Age Iconography: Shaping a Methodology*, eds R Laffineur & JL Crowley. Proceedings of the 4th International Aegean Conference, University of Tasmania, Hobart, Australia, 6-9 April 1992, *Aegeum* 8 : 307-316 and Plates LXXVI-LXXVIII. University of Liege, France.
1995. Fishy business: Studies of fishing in the prehistoric Aegean. *The Artefact* 18 : 76-79.

## Pullen DJ

1992. Ox and plough in the Early Bronze Age Aegean. *American Journal of Archaeology* 96 : 45-54.

## Rackham O

- 1972a. The vegetation of the Myrtos region. In: *Myrtos: An Early Bronze Age Settlement in Crete*, Appendix II, ed Peter Warren. London : Thames & Hudson, 283-298.
- 1972b. Charcoal and plaster impressions. In: *Myrtos: An Early Bronze Age Settlement in Crete*, Appendix III, ed Peter Warren. London : Thames & Hudson, 299-304.
1983. Observations on the historical ecology of Boeotia. *Annual of the British School at Athens* 78 : 291-351.

## Rackham O &amp; Moody J

1996. *The making of the Cretan landscape*. Manchester : Manchester University Press.

## Rahmani M

1989. Review of the role of chlorophyllous pigments in photo-oxidation of virgin olive oil. *Olivae* VI 26 : 30-32.

## Raison J &amp; Pope M

1971. *Index du Linéaire A*. Roma p. XV. Note 44.

## Ranalli A

1989. Aspects of and problems connected with the storage and preservation of olive oil. *Olivae* 27 : 11-18.

## Ratcliffe William

1921. *Fishing from the Earliest Times*. London : John Murray.

## Rehak P

1997. Interconnections between the Aegean and the Orient in the Second Millennium BC. Review article. *American Journal of Archaeology* 101 : 399-402.

## Renaud S, de Lorgé M, Delaye J, Guidollet J, Jacquard F, Mamelie N, Martin J-L, Monjaud I, Salen P &amp; Toubol P

1995. Cretan Mediterranean diet for prevention of coronary heart disease. *American Journal for Clinical Nutrition* 61 (Supplement) : 1360S - 1367S.

## Renfrew Colin

1972. *The Emergence of Civilisation. The Cyclades and the Aegean in the Third Millennium BC*. London : Methuen.

Renfrew Colin (ed)

1973. *The Explanation of Culture Change: Models in Prehistory*. London : Duckworth.

Renfrew C & Wagstaff M (eds)

1982. *An Island Polity*. Cambridge : Cambridge University Press.

Renfrew Jane

1973. *Palaeoethnobotany*. London : Methuen.

Rice RD

1990. Mediterranean diet. Letter to Editor. *Lancet* 344 : 893-894.

Riley FR

1974. Middle Minoan settlement patterns on Crete. Dissertation submitted to the University of Bristol for the degree of M.A. (Unpublished).

Roebuck C

1959. *Ionian Trade and Colonisation*. New York : American Institute of Archaeology.

Ronsivalli LJ.

1978. Sharks and their utilisation. *Marine Fisheries Review*, February 1978 : 1-13.

Rostovtzeff M

1941. *The Social and Economic History of the Hellenistic World*. Oxford : Clarendon Press.

Runnels CN & Hansen J

1986. The olive in the prehistoric Aegean: The evidence for domestication in the Early Bronze Age. *Oxford Journal of Archaeology* 5(3) : 299-308.

Runnels CN & van Andel TH

1987. The evolution of settlement in the southern Argolid, Greece: An economic explanation. *Hesperia* 56 : 303-334.

Sakellarakis E & Y

1984. The Keftiu and the Minoan Thalassocracy. In: *The Minoan Thalassocracy: Myth and Reality*. Proceedings of the Third International Symposium at the Swedish Institute in Athens, 31 May-5 June 1982, eds R Hagg & N Marinatos, 197-203. Distributed by Paul Astroms Forlag, Goteborg.

Sakellarakis JA

1982. *Illustrated Guide to the Herakleion Museum*. Athens : Edotike Athenon SA.

Sakellarakis Y & Sapouna-Sakellaraki E

1981. Drama of death in a Minoan Temple. *National Geographic* 159(2) : 204-223.

Salem N

1993. *Health policy aspects of lipid nutrition and early development*. Paper delivered at 1st International Congress of the International Society for the Study of Fatty Acids and Lipids, Lugano, Switzerland, 30 June-3 July 1993.

Sallares R

1991. *The Ecology of the Ancient Greek World*. London : Duckworth.

## Sanders GDR

1984. Reassessing ancient populations. *Annual of the British School at Athens* 79 : 251-262.

## Sarpaki A

1992. The palaeoethnobotanical approach. The Mediterranean triad or is it a quartet? In: *Agriculture in Ancient Greece*. Acta instituti Atheniensis Regni Suecae, Series in 4°, XLII. Proceedings of the 7th International Symposium at the Swedish Institute at Athens, 16-17 May 1990, ed Berit Wells : Stockholm, 61-75.

## Schliemann Henry.

1878. *Mycenae. A Narrative of Researches and Discoveries at Mycenae and Tiryns*. London : John Murray.

## Seager RB.

1909. Excavations on the Island of Mochlos, Crete in 1908. *American Journal of Archaeology* 13 : 273-303.

1910. Excavations on the island of Pseira. *Anthopology Publication III.1*. Philadelphia : University of Pennsylvania.

1912. *Explorations on the Island of Mochlos*. Boston and New York (Publisher not given).

## Seymour TD

1907. *Life in the Homeric Age* : New York & London.

## Shay J &amp; Shay T

1978. Modern vegetation and fossil plant remains. In: *Excavations at Nichosia in South West Greece, Vol. I. Site, Environs and Techniques*, eds G Rapp Jr & SE Aschenbrenner. Minneapolis : University of Minnesota, 41-59.

## Sheridan AS &amp; Bailey G (eds)

1981. *Economic Archaeology: Towards an Integration of Ecological and Social Approaches*. Oxford : British Archaeological Reports International Series 96.

## Sherratt AG

1981. Plough and pastoralism: Aspects of the secondary products revolution. In: *Pattern of the Past*, eds I Hodder, G Isaac & N Hammond. Cambridge : Cambridge University Press, 261-305.

## Sherratt ES

1990. Reading the texts: Archaeology and the Homeric Question. *Antiquity* 64 : 807-824.

## Simopoulos A

1990. Omega 3-fatty acids and illness. In: *Recent Advances in Clinical Nutrition and the Epidemiology of Nutritional Diseases*, eds A Kafatos & D Labidarios. Herakleion : University of Crete, 64-76.

## Smith JLB

1949. *The Sea Fishes of Southern Africa*. Johannesburg : Central News Agency Ltd.

## Smith Margaret

1975. *Common and Scientific Names of the Fishes of Southern Africa, Part I. Marine Fishes*. Grahamstown : JLB Smith Institute of Ichthyology.

## Smith Margaret M &amp; Heemstra PC

1991. *Smith's Sea Fishes*. Grahamstown : JLB Smith Institute of Ichthyology.

Snodgrass AM

1985. The new archaeology and the classical archaeologist. *American Journal of Archaeology* 8 : 31-37.

Soles JS

1979. The early Gournia town. *American Journal of Archaeology* 75 : 149-167.

Soles JS & Davaras C

1992. Excavations at Mochlos, 1989. *Hesperia* 61 : 413-445.

Spiller GA (ed)

1991a. *The Mediterranean Diets in Health and Disease*. New York : Van Nostrand Reinhold.

Spiller GA

1991b. Physiological effects of monounsaturated oils. In: *The Mediterranean Diets in Health and Disease*, ed Gene A Spiller. New York : Van Nostrand Reinhold, 182-194.

Stansby ME

1990. Nutritional properties of fish oil for human consumption. In: *Fish Oils in Nutrition*, ed ME Stansby. New York : Van Nostrand Reinhold.

Strøm A.

1948. Examination into the diet of Norwegian families during the war years 1942-45. *Acta Medica Scandinavica Supplement*. 1-47.

Stuart-Macadam PL

1988. *Nutrition and Anaemia in Past Human Populations*. Chacmool : 284-287.

Sverdrup HU, Johnson MW & Fleming RH

1942. *The Oceans: Their Physics, Chemistry and General Biology*. New York : Prentice Hall.

Terano T, Hirai A & Hamazaki T

1983. Effect of oral administration of highly purified eicosapentaenoic acid on platelet function, blood viscosity and red cell deformability in healthy human subjects. *Atherosclerosis* 46 : 321-331.

Theocharis D

1958. Ek tis prokeramikis Thessalias prosorini Anaskaphiki Ekthesis. *Thessalika A*.

Tomaritis M, Peraki E, Georgulli M, Kafatos A, Charalambakis G, Divanack P, Kentouri M, Yiannopoulos S, Frenaritou H & Argyrides R

1993. Fatty acid composition and total fat content of eight species of Mediterranean fish. *International Journal of Food Sciences and Nutrition* 45 : 135-139.

Trevisan M, Krogh V, Freudenheim J, Blake A, Muti P, Panico S, Farinaro E, Mancini M, Menotti A, Ricci G and Research Group ATS-RF2 of the Italian National Research Council

1990. Consumption of olive oil, butter and vegetable oils and coronary heart disease risk factors. *Journal of the American Medical Association* 263(5) : 688-692.

Tsountas C

1898. Kykladika I. *Archaiologike Ephemeris*.

1899. Kykladika II. *Archaiologike Ephemeris* : 73.

Uauy R, Birch D & Hoffman D

1993. *Omega-3 fatty acids for retinal and brain development of pre-term and term infants*. Paper delivered at 1st International Congress of the International Society for the Study of Fatty Acids and Lipids, Lugano, Switzerland, 30 June-July 1993.

United States National Research Council Recommended Dietary Allowances

1948. *Reprint and Circular Series No. 129*. Washington. October 1948 : 16-17.

Van Andel TH

1989. Late Quaternary sea level changes and archaeology. *Antiquity* 63 : 733-745.

1990. Addendum to Late Quaternary sea level changes and archaeology. *Antiquity* 64 : 152-153.

Van Andel TH & Runnels CN

1988. An essay on the "emergence of civilisation" in the Aegean world. *Antiquity* 62 : 234-247.

1995. The earliest farmers in Europe. *Antiquity* 69 : 481-500.

Van Andel TH & Shackleton JC

1982. Late Palaeolithic and Mesolithic coastlines of Greece and the Aegean. *Journal of Field Archaeology* 9 : 445-454.

Van der Elst R

1981. *A Guide to the Common Sea Fishes of Southern Africa*. Cape Town : C. Struik.

Van der Merwe NJ

1976. *Archaeology: The past in the service of the future*. University of Cape Town. Inaugural Lecture. New Series 36.

Van Effenterre H

1983. The economic pattern of a Minoan district: The case of Mallia. In: *Minoan Society: Proceedings of the Cambridge Colloquium 1981*, eds O Kryszkowska & L Nixon. Bristol : Bristol Classical Press, 61-68.

Ventris M & Chadwick J

1973. *Documents in Mycenaean Greek*. 2nd Edition. Cambridge : Cambridge University Press.

Vermeule E

1964. *Greece in the Bronze Age*. Chicago and London : University of Chicago Press.

Vial I, Muchnik E & Kain J

1991. The evolution of Chile's main nutrition intervention programmes. Article 3. *Food and Nutrition Bulletin* 13(3) : 389-397. United Nations University.

Von den Driesch A

1987. Haus- und Jagtiere im vorgeschichtlichen Thessalien. *Prähistorische Zeitschrift* 62 : 1-21.

Von Luschau

1913. *Zeitschrift fuer Ethnologie* : 307-393 (no title given, cited Glotz 1925 : 57).

Von Schacky C & Weber PC.

1985. Metabolism and effects on platelet function of the purified eicosapentaenoic and docosahexaenoic acids in humans. *Journal Clinical Investigations* 76 : 2446-2450.

Voss A, Reinhart M, Sankarappa S & Specher H

1991. The metabolism of 7,10,13,16,19-docosapentaenoic acid to 4,7,10,13,16,19-docosapentaenoic acid in rat liver is independent of 4-desaturase. *Journal of Biological Chemistry* 256(30) : 19995-20000.

Wagstaff M, Augustson S

1982. Traditional land use. In: *An Island Polity*, eds C Renfrew & M Wagstaff. Cambridge : Cambridge University Press, 106-133.

Wagstaff M, Augustson S & Gamble C

1982. Alternative substance strategies. In: *An Island Polity*, eds C Renfrew & M Wagstaff. Cambridge : Cambridge University Press, 172-180.

Wagstaff M & Cherry JF

- 1982a. Settlement and population change. In: *An Island Polity*, eds C Renfrew & M Wagstaff. Cambridge : Cambridge University Press, 136-155.  
1982b. Settlement and resources. In: *An Island Polity*, eds C Renfrew & M Wagstaff. Cambridge : Cambridge University Press, 246-263.

Wall SM, Musgrave JH & Warren PM

1986. Human bones from a Late Minoan Ib house at Knossos. *Annual of the British School at Athens* 81 : 332 - 388.

Walsh GP

1990. Dietary change and coronary heart disease. *Medical Hypotheses* 31 : 135-139.

Warren Peter

1972. *Myrtos. An Early Bronze Age settlement in Crete*, Volume No. 7. Oxford : British School at Athens.  
1973. Crete 3000-1400 BC: Immigration and archaeological evidence. In: *Bronze Age Migrations in the Aegean. Archaeological and Linguistic Problems in Greek Prehistory*, eds RA Crossland & Ann Birchall. London : Duckworth, 41-50.  
1985. Minoan palaces. *Scientific American*, July 1985 : 74-81.  
1987. The Genesis of the Minoan Palace. In: *The Function of Minoan Palaces*, eds R Hagg & N Marinatos. Proceedings of the 4th International Symposium at the Swedish Institute at Athens, Stockholm : Astroms Forlag, 47-55.

Warren P & Hankey V

1989. *Aegean Bronze Age Chronology*. Bristol : Bristol Classical Press.

Warren P & Tzedhakis J

1974. Debla, an early Minoan settlement in Western Crete. *Annual of the British School at Athens* 69 : 299-342.

Watrous LV

1975. Explorations on the Plain of Lasithi in Crete. *Athens Annals of Archaeology* 8 : 206.  
1982. *Lasithi: A History of Settlement on a Highland Plain in Crete*. Hesperia Supplement 18. American School of Classical Studies at Athens : Princeton, New Jersey.  
1984. Ayia Triada: A new perspective on the Minoan Villa. *American Journal of Archaeology* 88 : 123-134.  
1987. The role of the near east in the rise of the Cretan palaces. In: *The Function of Minoan Palaces*, eds R Hagg & N Marinatos. Proceedings of the 4th International Symposium at the Swedish Institutes at Athens. Stockholm : Astroms Forlag, 65-70.  
1991. The origins and iconography of the Late Minoan painted larnax. *Hesperia* 60 : 285-307.

1994. Review of Aegean prehistory. Crete from earliest prehistory through the protopalatial period. *American Journal of Archaeology* 98 : 695-753.

Watrouts LV, Valtianou D, Pope K, Mourtzas N, Shay J, Shay CT, Tsoungarakis D, Vallianos C & Blitzer H

1993. A survey of the western Mesara Plain in Crete: Preliminary Report of the 1984, 1986 and 1987 field seasons. *Hesperia* 62 : 191-248.

Watrouts L & Blitzer H

1995. The Gournia Survey Project: A preliminary report on the 1992-1994 field season. *American Journal of Archaeology* 99 : 313 (abstract).

Weinberg SS

1965. *The Stone Age in the Aegean*. Cambridge Ancient History I, Ch. 10. Cambridge : Cambridge University Press.

Weinstein JM

1992. Review of Black Athena: The Afroasiatic roots of Classical Civilization II: The Archaeological and Linguistic evidence by Martin Bernal. *American Journal of Archaeology* 96 : 381.

Wells B (ed)

1992. *Agriculture in Ancient Greece*. Acta instituti Atheniensis Regni Suecae, Series in 4°, XLII. Proceedings of the 7th International Symposium at the Swedish Institute at Athens, 16-17 May 1990, Stockholm.

Whitelaw T

1983. The settlement at Fournou Korifi, Myrtos and aspects of social organisation. In: *Minoan Society*, eds O Kryzyszkowska & L Nixon. Bristol : Bristol Classical Press, 323-345.

Winder NP

1991. Interpreting a site: The case for reassessment of the Knossos Neolithic. *Cambridge Archaeological Review* 10(1) : 27-51.

Wing Elizabeth S & Browne Antoinette

1979. *Palaeonutrition*. New York : Academic Press.

Wood PDP

1981. A possible selection effect in medical science. *The Statistician* 30(2) : 131-135.

Xanthoudides S

1924. *The Vaulted Tombs of the Mesara*. University Press of Liverpool Ltd, London : Hodder & Stoughton.

Young FVK

1988. The chemical and physical properties of crude fish oils for refiners and hydrogenators. *IAFMM Fish Oil Bulletin* No. 18. International Association of Fish Meal Manufacturers, London.

Zohary D & Spiegel-Roy P

1975. Beginning of fruit growing in the old world. *Science* 198 : 319-327.

Zvelebil M

1986. Review of Ammerman & Cavalli-Sforza (1984). *Journal of Archaeological Science* 13(1) : 93-95.

## 9.2 Classical Bibliography

Aelian	On the Nature of Animals
Aeschylus	Persians
Aristotle	On the History of Animals
Athenaeus	The Deipnosophists
Galen	On Medicine
Hippocrates	On Diet
Homer	The Iliad
	The Odyssey
Oppian	The Halieutica
Pliny	Pliny the Elder. Natural History
Plutarch	S(apientia) A(nimalium) = On the Intelligence of Animals
Strabo	Geography
Xenocrates	On Medicine

## 10. APPENDIX

### 10.1 Method of analysis for olive and fish fatty acid composition and content

A portion of the lipids (about 0.2 g), obtained by extraction and evaporation *in vacuo*, was refluxed with 5 ml of a 0.5M solution of sodium hydroxide in methanol for about 10 min. After saponification 5 ml of a 15% solution of borontrifluoride in methanol was added and the mixture refluxed for 2 min. then 5 ml of hexane was added through the top of the condenser and the mixture refluxed for another 1 min. The flask was removed and sufficient saturated sodium chloride solution was added to make the hexane solution of the methyl esters rise into the neck of the flask. The methyl esters in the hexane were removed with a pasteur pipette, dried over anhydrous sodium sulphate, filtered and injected direct into the 5710A Hewlett Packard gas chromatograph. The methyl esters were separated on a 48 m glass capillary column with an internal diameter of 0.3 mm having a Silar 10C coating and using hydrogen as carrier gas. The temperature was programmed from 140-230°C rising 4° min<sup>-1</sup> while the injection port remained at 250°C. Quantitation was carried out by a Hewlett Packard 3353 Lab Data System (De Koning *et al* 1983).

## 10.2 Minoan Chronology

Date BC	Early (Higgins 1967:13)	Warren & Hankey (1989:137)	Betancourt Archaeometry 29 (1987:45)	Egyptian Dynasty/Kingdom (Higgins 1967:13)
3500		EM I		
3400				
3300				
3200				
3100				1st Old
3000				
2900		EM II A		2nd Old
2800	EM I			
2700				3rd Old
2600				4th Old
		EM II B		
2500	EM II			5th Old
2400				
				6th Old
2300		EM III/ (MM I A)		
2200	EM III			7th 1st Inter
		MM I A		
2100				
				10th 1st Inter
2000				11th Middle
	MM I			
1900	MM II	MM I B/II A		
1800			MM III	12th Middle
		MM II B/III A		13th
1700	MM III	MM III B	LM I A	
				15th Hyksos
1650				
			<u>THERA ERUPTION</u>	
1600		LM I A, I B	LM I B	18th New Kamose Ahmose Amenhotep I
1550	LM I A		LM II	
				Thutmosis I Thutmosis II Hatshepsut
1500	LM I B	<u>THERA ERUPTION</u>	LM III A1	Thutmosis III Amenhotep II Thutmosis IV Amenhotep III
1450	LM II	LM II/III A1	LM III A2	
1400	LM III A			Akhenaten
				Tutankhamen Horemheb
1350		LM III A2	LM III B	19th New
1300	LM III B	LM III B		
1200	LM III C	LM III C	LM III C	20th New
1100				
	DARK AGES	SUBMINOAN		
1000				