MESOLITHIC FISHING AND SEAFARING IN THE AEGEAN

A Thesis

by

THANOS ARONIS WEBB

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

August 1999

Major Subject: Anthropology
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ABSTRACT

Mesolithic Fishing and Seafaring in the Aegean. (August 1999)

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Melian obsidian and fish bones unearthed at Franchthi cave confirm the existence of seafaring in the Aegean Sea since the Late Paleolithic. By the Mesolithic, an increase in the quantity of obsidian occurs contemporaneously with the appearance of bones from bluefin tuna weighing up to 200 kg. Even though direct archaeological evidence which reflects the type of boats and fishing practices used to acquire these fish does not exist, evidence in the form of migration theory and fish preservation suggests that the Aegean sailors had a sophisticated technology capable of building planked hulls and preserving tuna.
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CHAPTER I
INTRODUCTION

Evidence for Mesolithic seafaring and fishing in the Aegean goes far beyond the archaeological remains of Melian obsidian and tuna bones found at Franchthi cave. Whereas the presence of obsidian at the cave secures the existence of seagoing boats, evidence from later Neolithic migration and colonization of Crete and mainland Greece suggest that these boats were more technologically advanced than most scholars believe. Archaeologists usually refer to the community's simple tool kit as an indicator of technological level. It is a mistake to make such an argument when studying early Aegean seafaring and fishing.

The capture and preservation of tuna also reflect a progressive level of technology that can be gleaned from current research in fisheries science as well as archaeological evidence. Catching and preserving bluefin tuna continue to frustrate modern fishermen and researchers. This fact makes the accomplishments of the inhabitants of Mesolithic Franchthi as tuna catchers even more remarkable. There is no evidence hinting at the type of fishing techniques employed to harvest tuna weighing over 200 kg or how they were kept from becoming rancid after being pulled from the sea. Both issues require that we make assumptions concerning sophisticated procedures without direct evidence. As mentioned above in reference to boats, I believe that we are required to give these prehistoric mariners knowledge and abilities that are usually equated with peoples from much later periods.

This thesis follows the style and format of the American Journal of Archaeology.
This thesis presents an overview of current arguments concerning Mesolithic seafaring. Support is provided by the type of boat that was needed to colonize Neolithic Crete. By using migration theory, I show how the evidence suggests the possibility of planked hulls during the Mesolithic period. I focus on fishing practices, materials available to construct fishing tackle, and preservation techniques available to Mesolithic people in the Aegean that redefine our conception of the maritime activities and technology during this period. To fill gaps in the maritime narrative requires the use of later archaeological and historical evidence. Also, such an analysis would be impossible without Mark Rose’s identification of the fish remains from Franchthi cave. His classification down to species allows me to focus on particularities of bluefin tuna. This animal’s unique physiology and behavior act as a powerful data set that will be used to test the possibilities of certain theories and the impossibilities of others.
CHAPTER II
HISTORICAL BACKGROUND

Archaeological evidence for fishing and seafaring in the Aegean during the Mesolithic is sparse yet provocative. Lack of sites forces researchers to reconstruct this period’s 2000 year history (9th-8th millennium B.C.) with the cultural remains from only one excavation: Franchthi cave located in the southern Argolid, Greece (fig. 1). In the late 1960’s, American archaeologists unearthed finds displaying continuous habitation at the cave from the Final Paleolithic to the Final Neolithic (11th-4th millennium B.C.).\(^1\) Of these finds, the discovery of obsidian unique to the island of Melos in the Final Paleolithic levels constitutes the earliest indication of seafaring in the Aegean. This claim arises from the fact that landfall on Melos was impossible without a boat.\(^2\) Consequently, mainland inhabitants had to sail over 150 km in order to acquire the volcanic glass. This Final Paleolithic exploration by boat increased through the millennia and, as a result, Mesolithic sailors fostered an intimate knowledge of the islands and surrounding land masses touched by the Aegean Sea.\(^3\)

In the Upper Mesolithic (8th millennium B.C.), an increase in the quantity of Melian obsidian along with the first appearance of large bluefin tuna bones (Thunnus thynnus) underscores the community’s continued waterborne expertise. Recovered tuna vertebrae are a testament to the skill of the extraordinary fishermen who caught


\(^3\)Cyrian Broodbank and Thomas F. Strasser, “Migrant Farmers and the Neolithic Colonization of Crete,” *Antiquity* 65 (1991) 235 and Powell (supra n. 2) 49.
specimens weighing over 200 kg and measuring up to two meters in length. This feat becomes even more impressive and elusive since artifacts reflecting the boats, tackle, or capture techniques of these fishermen have not been found.

Fig. 1

Traditionally, the necessities of tuna fishing suggest that it was practiced by technologically advanced societies. Boats using nets with assorted floats and sinkers are seen as mandatory equipment. John L. Bintliff proposes a scenario concerning the technique for hunting these fish: "The large tunny catch is of necessity tied closely to the

---

4 Rose (supra n. 1) 19.

use of boats, and efficient hauls require the cooperation of several boats to surround the
school and pull up a large net or drag the net into shore seine-fashion (fig. 2).”

Fig. 2

He bases this hypothetical tuna harvest on historical evidence and not material
remains. This negative evidence of fishing gear, including fishhooks which are absent
from the Aegean tackle box until the Neolithic, can reflect poor preservation rather than
a low technological level. Nets, lines, and hooks would have all been made from
perishable materials. Nevertheless, we are still left with the task of reconstructing
fishing practices in light of available data.

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Relevant data appears in many forms other than artifacts recovered through excavation. For example, to explain the relationship between a contemporaneous presence of tuna and a marked increase in Melian obsidian during the Mesolithic, some scholars believe that trips to Melos doubled as an opportunity to hunt for tuna.\textsuperscript{7} According to this scenario, boats navigated by hugging the mainland coastline for safety purposes and then island hopped south to Melos rather than venturing across wide expanses of open-sea. Two islands passed via this stepping stone route are Euboea and Andros. Jameson states that given the location of ancient coastlines, these islands would be ideal feeding grounds for tuna due to upwelling caused by westerly winds in spring.\textsuperscript{8} These winds create sea currents that bring nutrients from the cold depths to the surface where they are consumed by plankton, which were subsequently eaten by the small fish that make up the bulk of a tuna’s diet (fig. 3).\textsuperscript{9} The sight of a shoal of tuna, sometimes hundreds of them, devouring their prey along with the chaos created on the surface of the sea could have enticed the curiosities of Melos-bound sailors. In fact, modern fishermen still locate tuna by scanning the seas for foamy, boiling water that is usually accompanied by scavenging seagulls flying directly over the mayhem.\textsuperscript{10}

Therefore, before returning home with a cargo of obsidian, sailors could have taken full advantage of their long distance voyage and fished these tuna grounds as well. At first

\textsuperscript{8}Van Andel and Runnels (supra n. 7) 238.
\textsuperscript{9}Rose (supra n. 1) 18.
Fig. 3

Fig. 4
glance, Jameson’s belief that the insular feeding grounds and sailing route to Melos constitute more than a coincidence appears plausible (fig. 4).

Jameson’s theory, however, is not universally accepted. Criticism forwarded by Mark Rose challenges its feasibility. He points out that in Van Andel and Sutton’s reconstruction of the 7000 B.C. coastline used by Jameson, he fails to explain why tuna were caught off distant Cycladic Islands rather than in upwelling areas within close proximity to Franchthi.\(^{11}\) If we take a close look at their map, it is clear that upwelling occurs off the coasts of the Saronic Gulf and the eastern Peloponnese. Rose points out that Jameson ignores these areas as potential fishing grounds for tuna. He suggests that since tuna is a perishable item, they would have to be taken in waters within close proximity to the cave.\(^{12}\) Rose states:

> Another objection may be raised given that the tuna remains at Franchthi represent whole fish (or parts of them); tail and fin elements, vertebrae, and cranial and facial bones are all present. Are we to believe then that the Mesolithic inhabitants of the cave transported tuna carcasses from the waters off the east coast of Euboea to Franchthi, a distance of 200 km or more? While the presence of large tuna and Melian obsidian indicate the Mesolithic inhabitants of Franchthi were capable mariners, there are obvious differences between tuna (high bulk, perishable) and obsidian (low bulk, imperishable) as cargoes or commodities.\(^{13}\)

In other words, by the time a boat loaded with tuna traveled 200 km to Franchthi en route from the Cyclades, its fish cargo would be nothing more than a pile of rotten, spoiled carrion. Rose argues that the fish were taken in areas close to the cave in order to shorten the period of time after harvesting before the flesh has a chance to deteriorate.

\(^{11}\)See Tjeerd van Andel and S.B. Sutton, *Landscape and People of the Franchthi Region* (Bloomington 1987) 55 for upwelling areas.

\(^{12}\)Rose (supra n. 1) 19.

\(^{13}\)Rose (supra n. 1) 19.
If we take his line of reasoning a step further, Rose is making the implicit assumption that Mesolithic fisherman had no way of preserving their catch. He argues, and rightly so, that there are other locations to fish for tuna than the ones suggested by Runnels and Van Andel. He places his fishermen closer to Franchthi because of the perishable nature of fish. Without some form of preservation, the fishing grounds he mentions off the coasts of the Saronic Gulf and the eastern Peloponnese would have also resulted in hunters returning home with potentially rotten fish. By using the Chumash Indians from California as an ethnographic example, we are able to approximate the amount of time needed to travel by a paddled boat in the Aegean. For distances greater than 32.2 km, a replica of a Chumash planked canoe averaged a speed of 5.5 km/h.\textsuperscript{14} Using this speed, Table 1 shows the length of time required to sail to the various fishing grounds throughout the Aegean. Due to specifics of a bluefin tuna’s physiology, if left unattended for 12 hours or more, in some cases, those who ate the flesh would become sick on account of spoilage bacteria having ample time to multiple and ruin the meat.

\textsuperscript{14}Fernando Librado, “Plank Canoe: Uses,” in Travis Hudson, Janice Timbrook, and Melissa Rempe eds., \textit{Tomol: Chumash Watercraft as Described in the Ethnographic Notes of John P. Harrington}
Table 1
Possible searoutes, distance, speed, and traveling time in the Aegean.

<table>
<thead>
<tr>
<th>Franchthi to</th>
<th>Distance</th>
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<th>Travel Time</th>
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<tr>
<td>S. Peloponnese (Akra Tourkovigla) via Spestes</td>
<td>65km</td>
<td>5.5km/h</td>
<td>12 hours</td>
</tr>
<tr>
<td>S. Peloponnese (Akra Tourkovigla) coastal route via Nauplion</td>
<td>93km</td>
<td>5.5km/h</td>
<td>16 hours</td>
</tr>
<tr>
<td>Poros (Saronic Gulf)</td>
<td>93km</td>
<td>5.5km/h</td>
<td>16 hours</td>
</tr>
<tr>
<td>Sounion direct</td>
<td>148km</td>
<td>5.5km/h</td>
<td>26 hours</td>
</tr>
<tr>
<td>Melos via Velopoula-Falkonera</td>
<td>170km</td>
<td>5.5km/h</td>
<td>31 hours</td>
</tr>
<tr>
<td>Sounion via Poros-Aigina-Glifada</td>
<td>194km</td>
<td>5.5km/h</td>
<td>35 hours</td>
</tr>
<tr>
<td>Andros/Eubia via Sounion direct</td>
<td>250km</td>
<td>5.5km/h</td>
<td>45 hours</td>
</tr>
<tr>
<td>Melos via Sounion direct-Kea-Kithnos-Seriphos-Siphnos</td>
<td>296km</td>
<td>5.5km/h</td>
<td>54 hours</td>
</tr>
<tr>
<td>Melos via Sounion direct-Andros-Tinos-Mykonos-Paros-Siphnos</td>
<td>454km</td>
<td>5.5km/h</td>
<td>82 hours</td>
</tr>
</tbody>
</table>

It is still possible, however, under ideal circumstances and proper post-harvest processing that bluefin tuna could have been eaten even after a 12-hour voyage.

Consequently, the longer a fish remains unprocessed, the more difficult it is to preserve

(Santa Barbara 1978) 137.
because as time passes, rancid and spoiling bacteria become increasingly active.\textsuperscript{15} For example, recent studies report that for every hour a tuna is exposed to ambient temperatures of 28°-30°C before preservation, the fish losses 1 day of shelf life.\textsuperscript{16} In other words, if a Mesolithic fishermen wanted to store tuna for later use rather than consume it immediately, the earlier they initiated the preservation process, the better their chances were for long term storage.\textsuperscript{17} The next logical question is to look at the cultural remains for clues reflecting tuna storage in order to support the claim that fish preservation was practiced.

Evidence which may corroborate the existence of fish preservation during the Mesolithic can be seen in archaeological remains showing that Franchthi cave was inhabited year round. Analysis of Upper Mesolithic burials shows that up to 25 individuals including both sexes and all age groups from neonates to adults were interred at the site.\textsuperscript{18} Curtis Runnels states that “the conclusion is inescapable that we are dealing with a permanent settlement with the full spectrum of the social group.”\textsuperscript{19} If we juxtapose this observation and the fact that over 50% of the all the faunal remains recovered from the cave were bluefin tuna bones, we can assert that tuna played more than a seasonal role.\textsuperscript{20} The dominance of tuna in the faunal record supports the

\begin{footnotesize}
\begin{enumerate}
\item Board on Science and Technology, \textit{Fisheries Technology for Developing Countries} (Washington, D.C. 1988) 144.
\item Brian K. Mayer and Donn R. Ward, Microbiology of Finfish and Finfish Processing,” in Donn R. Ward and Cameron Hackney eds., \textit{Microbiology of Marine Food Products} (New York 1991) 7.
\item Mayer and Ward (supra n. 16) 7.
\item Runnels (supra n. 18) 722.
\item See S. Payne, “Faunal change at Franchthi Cave from 20,000 B.C. to 3,000 B.C.,” in A.T. Clason ed., \textit{Archaeozoological Studies} (Amsterdam 1975) 122 and Runnels (supra n. 19) 722.
\end{enumerate}
\end{footnotesize}
likelihood that surplus tuna were preserved to guard against leaner times during the year.\textsuperscript{21}

Thus Rose's dismissal of voyages to acquire Melian obsidian doubling as an opportunity to fish for bluefin tuna loses its strength if Mesolithic seafarers knew how to preserve their catch. Such knowledge would allow them to procure tuna from any fishing ground or location throughout the Aegean. As discussed in the next section, mariners reached the Cycladic Islands and adjacent land masses during the Mesolithic with boats built to withstand the pounding of the open sea and serve as fishing platforms. Similar to the assumption held by Rose that Franchthi's fishermen lacked the knowledge of preservation, most scholars believe that the Mesolithic tool kit was inadequate to construct sophisticated hulls. Evidence supplied by migration data, however, suggests otherwise.

\textsuperscript{21}Wheeler and Jones (supra n. 5) 28.
CHAPTER III

BOATS AND SEAFARING

One of the most elusive periods in Aegean Prehistory is the Mesolithic to Neolithic transition. In its broadest terms, this shift is defined by the arrival of domesticated plants and animals from the Near East and/or Anatolia during the 7th millennium B.C. At Franchthi Cave for example, faunal evidence shows that wild deer, pig, rabbit, and tuna fill the Mesolithic levels and domesticated goat and sheep dominate 90% of the faunal material in the Neolithic.\(^2\) This dramatic change in subsistence base is seemingly due to migrating peoples from the east bringing their knowledge of domestication with them.\(^3\) This theory of migration hinges on specifics relating to the sea savvy and shipbuilding technology of Aegean mariners. Most scholars tend to view the Aegean Sea as the enabling mechanism which facilitated ideas and people to traverse prehistoric distances. This statement, though partially correct, must also include the boat itself and those who regularly plied the sea. By asking something as simple as what type of boat was available to Mesolithic sailors, we can begin to look at the migration model from a practical perspective.

In Cyprian Broodbank and Thomas Strasser’s article “Migrant Farmers and the Neolithic Colonization of Crete,” the authors forward a model detailing the essential items needed by migrants brought to guarantee their success. They believe that Crete was a well known landfall prior to its being permanently colonized. As sailors explored

\(^2\)Payne (supra n. 20) 122, 128-9.
the southern Aegean islands and fished insular waters, they became well acquainted with the location of Crete for two reasons. Firstly, due to the height of its mountain range and its overshadowing clouds, a person standing on the island of Melos or Santorini could see these features over 100 km away.24 Secondly, if while voyaging in the southern Aegean a boat were swept south because of strong northerly winds prevalent during optimal summer sailing months, chances are the boat would end up somewhere on the north coast of Crete.25 In other words, when people decided to set out from the mainland for Crete, they did not do it blindly. They probably had intimate knowledge of what to expect from previous exploration. This knowledge allowed them to plan their trip across the sea accordingly. Broodbank and Strasser believe the minimum package to guarantee survival of a colony consisted of 40 people with 10-20 pigs, 10-20 goats and sheep, 10-20 cattle, and 10,000 kg of grain.26 In early Neolithic settlements in the Aegean, the average settlement size of small villages tends to range from 40 to 200+ inhabitants. It is necessary to have 10-20 animals of each species because “wild life management studies have shown that under optimal conditions in which the initial [animal] population is not inbred (heterogeneous), genetically variant (heterozygous) and of reproductive age, 5-10 carefully chosen pairs can create a founder population with sufficient genetic diversity to maintain viability.”27 The authors also estimate 250 kg of grain per person was needed. This number reflects grain needed for planting and for feeding the population for one year due to the probability that the yield from the first year’s harvest would be poor.

24Broodbank and Strasser (supra n. 3) 235.
25Broodbank and Strasser (supra n. 3) 235.
26Broodbank and Strasser (supra n. 3) 237.
Thus, at the bare minimum, the migrants had to ship a cargo weighting 15,450-18,900 kg, including passenger weight. 28 With such a heavy load, assumptions can be made as to what type of boat made the migration possible.

Broodbank and Strasser suggest, and rightly so, that boats used in the Cretan migration had to be more substantial than a raft. 29 A raft refers to a vessel that floats because of the buoyancy of the construction material. In many communities throughout the world, Peru, Greece, and Egypt to name a few, rafts consist of a bundle of hollow reeds lashed together. However, if the intended cargo was grain and large animals, a watertight vessel would have been necessary in order to keep seeds from spoiling due to moisture, as well as being stable and strong enough to support the weight and temperament of a waterborne cow. The authors suggest hide boats or logboats as unlikely possibilities because they are vulnerable to heavy loads. 30 Unfortunately, there is no archaeological or iconographic evidence for boats for another 3000 years. Even though Broodbank and Strasser dismiss the use of certain boat types, they also fail to suggest an alternative within the domain of Neolithic tool technology. They believe a new “...purpose-built craft would have to be constructed” at this time to make the migration possible due to the above mentioned seed and animal problems. 31 These craft would then make up a flotilla of boats, 10-15 carrying one or two tons of cargo each, all making the crossing at once in order to have the whole “...Neolithic ‘package’

27 Broodbank and Strasser (supra n. 3) 240.
28 Broodbank and Strasser (supra n. 3) 240.
29 Broodbank and Strasser (supra n. 3) 241.
30 Broodbank and Strasser (supra n. 3) 241.
31 Broodbank and Strasser (supra n. 3) 241-2.
successfully transplanted.”32 In sum, they argue for the construction of specialized boats, and for boats that can carry at least one ton of cargo. These two points require a more in depth analysis.

In my opinion, in both practical and theoretical terms, a “purpose-built” craft seems highly unlikely for the Neolithic migration to Crete. David Anthony, in “Migration in Archaeology: The Baby and the Bathwater,” presents a processual model for patterned behavior in migrations based on research carried out by geographers, biological anthropologists, applied anthropologists, and sociologists.33 He discovered that the conditions favoring successful long distance migration are (1) stresses in the home region; (2) attraction in the destination region; (3) access to the information concerning a potential destination; and (4) transportation costs and technology.34 In other words, ease of transportation plays a crucial role in the decision making process of groups willing to migrate. Since I agree with this point, I feel that before the choice to leave home was made, the transportation technology that would facilitate a grand scale migration to Crete already existed. The most difficult part of the move to Crete was the sea crossing. I cannot imagine that this most crucial element was not long established prior to any decision being made.

Anthony’s third condition concerning the intimate knowledge of the destination prior to migration also plays an important role. Individuals planning to embark for Crete not only knew whether or not such a crossing was possible, but they also knew details of

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32 Broodbank and Strasser (supra n. 3) 241.
the island's farming and herding potential. In terms of Anthony's theory, reconnaissance must have occurred before any decision to migrate. This idea fits nicely with Broodbank and Strasser's argument that the southern Aegean was well known to mainland mariners at an early date. Since the Final Paleolithic, inhabitants from the mainland voyaged 150 km to the island of Melos in order to collect obsidian. By the Mesolithic, sailors were also able to land 50-200 kg tuna in open water. Whatever fishing techniques were employed, the boats of these early fishermen were stable and strong enough to support the violent death throes of a thrashing giant tuna. Thus, I believe the possibility of planked hulls during the Mesolithic needs to be considered.

Broodbank and Strasser equate a lack of sophistication in the Mesolithic and Neolithic tool kit to their inability to construct a complex, planked hull. John Cherry, agreeing with this argument states that "large, sophisticated ships became feasible only with the introduction of metal which allowed elaborate joinery and precision cutting of big wooden members. Even dugout canoes would present constructional difficulties." 

Cherry's statement is incorrect. There are ethnographic examples of planked hulls being made with simple tools. For instance, Chumash Indians who inhabited the coast of southern California constructed planked boats up to 9m in length with stone,

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34Anthony (supra n. 33) 896, 899.
36Mark J. Rose, With Line and Glittering Bronze Hook: Fishing in the Aegean Bronze Age (Diss. Indiana University 1994) 434-5.
37Broodbank and Strasser (supra n. 3) 241.
bone, and shell tools. They made their planks from locally available soft woods such as redwood and pine. These tree types are not only easy to work, but their porous cell structure causes the wood to swell when wetted, which tightens seams between planking to stop leaks. Wood was split into planks 2 cm thick and shaped by means of deer antler, sharpened stone, and clam shell tools. Chumash used sharkskin sandpaper during the final shaping to achieve tight fitting seams. The boat was then temporarily assembled by placing tar on plank edges and then joined together. Stone drills were employed to bore holes in planks which were then lashed together with rope. Finally, waterproofing tar was applied to the wetted surfaces.

I believe that even with the Aegean Mesolithic tool kit, such boats were possible with the available technology. To argue against sophisticated boat building based on technological level is a mistake. From the Chumash example, having simple tools only meant that more construction time was needed. "No one hurried them up—it was not like the whites. The Indians wanted to build good canoes...Sometimes the Indians would finish building a canoe in about 40 days, but sometimes it took from two to six months before it was done." When time is not a factor, we must reconsider what limitations we ascribe to ancient technologies. Furthermore, the fact that the early

39 Rosalind Perry, Lynn Roche, Pam Hoeft, Jan Timbrook, Patricia Campbell and Nick Miller, California Chumash Indians (Santa Barbara 1986) 31.
40 Perry et al. (supra n. 39) 31.
41 Perry et al. (supra n. 39) 31.
42 Perry et al. (supra n. 39) 31.
Neolithic site of Servia shows evidence of a wooden floor constructed from wooden planks obviously rules out the lack of tools argument.43

The evidence for early seafaring and fishing, along with need and possible ability to construct strong, stable boats underscore the expertise of early Aegean sailors. After 3000 years of plying the Aegean, I feel that innovation took place on the beaches of the Mesolithic shipwright, not those of an aspiring Neolithic migrant as suggested by Broodbank and Strasser. One thing that appears certain is when those wanting to migrate came to the shores of the Aegean, they encountered a seafaring culture with the ability to make their relocation a reality.

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CHAPTER IV
PASTORALISM AND SEAFARING

To better understand the continued role Mesolithic seafaring played during the Neolithic, seasonal pastoralism as a possible replacement mechanism for long distance exchange and interaction between settlements must also be considered. With the arrival of domesticated animals and the associated culture of animal husbandry from the Near East during the 7th millennium B.C., Neolithic Greece experienced an almost complete abandonment of Mesolithic hunting practices. Thomas Jacobsen believes this shift in faunal resources was accompanied by shift in human behavior at Franchthi cave. Using historical evidence of pastoralism from the southern Argolid to illuminate Neolithic practices, he explains that herding in the region required communities to engage in seasonal pastoralism.44 In practice, a shepherd escorts flocks to higher, greener altitudes good for grazing during dry summer months.45 Furthermore, pastoralists from this region live in distant villages during winter and often aggregate in the same or nearby pastures during summer. Jacobsen argues that at these yearly gatherings, shepherds used exchanges of resources to institute and reestablish ties with their fellow pastoralists. He states, “seasonal pastoralism served as a significant mechanism of exchange in prehistoric Greece and contributed to interaction within and (very likely) between

44 Cherry (supra n. 38) 9.
geographic regions.” Jacobsen also uses conclusions made by Tracy Cullen in her analysis of painted Neolithic pottery from the Argolid to strengthen his theory.

Cullen discovered that pottery from Franchthi cave has more stylistic similarities to distant sites such as Corinth than with adjacent communities. At first glance, it would seem more reasonable for neighboring sites to have artistic parallels. But as Cullen points out, competition between villages for the same natural resources might have forced differences in style, “while distant settlements established a symbolic relationship through stylistic likeness or act as nodes in an exchange network.” Armed with Cullen’s conclusions and the historical evidence, Jacobsen’s argument for seasonal pastoralism as a unifying mechanism seems tempting.

As Cherry points out, however, this argument for seasonal pastoralism during the Neolithic reflects historical subsistence practices and fails to consider prehistoric environmental factors and farming methods. Pollen analysis suggests that the treeless upland and lowland pastures seen today were a product of historical deforestation for the purpose of lumber as well as to expand grazing lands. Even though gradual clear cutting took place to facilitate early agriculture, its impact on the existing forests would have been minimal. This environmental scenario makes grazing of large numbers of animals unrealistic due to the paucity of suitable grass and the difficulty of managing a

46 Jacobsen (supra n. 45) 30.
48 Cherry (supra n. 47) 11.
49 Cherry (supra n. 47) 9.
50 Cherry (supra n. 47) 15.
51 Cherry (supra n. 47) 15.
herd amongst trees. A small flock of sheep and goats could be maintained without the need of extensive pastures, plus they could be used in cooperation with agriculture. The impracticality of large herds also played a role in early farming strategies due to a need for manure to obtain bountiful harvests. Farmers chose to cultivate land in close proximity to their villages in order to easily transport human wastes for fertilizer. Similarly livestock grazed on post-harvest plant remains to replenish nutrients in the soil with their manure. If large herds existed, farmers would be forced to produce immense amounts of food for their animals or, as mentioned above, transport them to distant pastures in search of sustenance. The fact that a sheep produces 10 times its body weight in manure per year, seasonal pastoralism would result in a huge loss of fertilizer in a region where the soil is exceptionally poor. Thus, by focusing on the environmental restrictions and farming strategies, Cherry argues for a symbiotic relationship between agriculture and localized pastoralists wherein shepherds moved a small number of animals short distances from their villages in order to take full advantage of each other’s resources. Most importantly, he weakens the idea of seasonal pastoralism as an exchange mechanism. This observation requires a reevaluation of Cullen’s pottery analysis concerning stylistic similarities between distant sites, like Corinth, in the Argolid.

The absence of pastoralism as a medium facilitating village interaction reinforces the use of boats as the most probable vehicle for developing and maintaining exchange

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52 Cherry (supra n. 47) 15.
53 Cherry (supra n. 47) 21.
54 Cherry (supra n. 47) 21.
networks. Due to shore-hugging navigation practices, littoral settlements set up *emporia* that probably date to the Mesolithic\(^{56}\) I believe this statement can be made based the evidence of seafaring and fishing both occurring since the Paleolithic.

\(^{55}\)Cherry (supra n. 47) 16.

\(^{56}\)Van Andel and Runnels (supra n. 7) 230.
CHAPTER V
FISHING TECHNIQUES

BACKGROUND

Many scholars believe that terrestrial hunting societies will look to the sea for alternative means of subsistence.\(^5^7\) The theory suggests that diminishing game on land forced communities to supplement their diets with seafood. When food items on land became increasingly scarce and required more energy to hunt or find, societies began to exploit the marine resources on the beaches and in the shallows. As time passed and the returns decreased while the amount of work increased, humans most likely employed some type of boat to harvest the rich marine environment beyond the shallows.\(^5^8\)

This gradual transformation to a boat-based fishing economy can be deduced from faunal remains at Franchthi cave in Greece. Judith Powell states that "we have evidence for fishing before there is evidence for the arrival of obsidian, I would suggest that fishing provided the nautical skills which allowed for exploration and exploitation of island resources."\(^5^9\) In the Final Paleolithic levels at Franchthi, most of the bones were from wild deer, horse, and goat, but 1% were littoral fish bones from eel (\textit{Anguilla anguilla}), sea bream (\textit{Diplodus sargus/vulgaris/annularis}), and gray mullet


\(^{58}\text{David R. Yesner, } \text{Life in the 'Garden of Eden': Causes and Consequences of the Adoption of Marine Diets by Human Societies,} \text{ in Marvin Harris and Eric B. Ross eds., Food and Evolution (Philadelphia 1987) 287-88.}\)
(Mugilidae). These fish species are found in both shallow and deeper waters. Their exploitation would require a certain level of fishing technology. The idea that fish were hunted with flint-topped spears is a strong possibility in the waist-deep shallows, but this method would produce a limited return in the shallows and be ineffective in deeper water. If hunters waded chest deep into the sea, the thrust of the spear was too slow to impale fast-swimming fish like the sea bream without the use of a boat as a fishing platform. Powell believes that small meshed nets were used catch sea bream, and possibly a hook and line to land grouper. In Classical times, fish species identical to those found in the Final Paleolithic levels at Franchthi were caught with beach seines like the one described by Bintliff above.

Two thousand years pass after the Final Paleolithic, during the Upper Mesolithic, a major shift occurs in faunal remains from Franchthi. Large bluefin tuna (Thunnus thynnus), grouper (Epinelphelus sp.), and barracuda (Sphyraena sphyraena) appear, comprising over 50% of the total bone weight. Land animals still supply a large percentage of bone remains, but eel is no longer present, and sea bream and gray mullet exist in reduced numbers. Analysis of these data sets reflecting the percentage of specific fish species provides insight for the examination of three aspects of early fishing: the marine habitat of the fish, the intensity of their exploitation, and the technology necessary for capturing various fish in their different marine habitats. By

59Powell (supra n. 2) 49.
60Payne (supra n. 20) 122.
61Powell (supra n. 2) 50.
62For ancient authors' descriptions of techniques for catching different fish, see Rose (supra n. 36) 185-86.
using the Upper Mesolithic tuna bone data from Franchthi cave, I will elucidate these points.

Most scholars agree that the abundance of tuna bones from Franchthi shows that the community’s quest for tuna was deliberate rather than accidental and required a certain level of fishing technology and waterborne expertise. Tuna travel in large schools in the deep water over the continental shelf during their seasonal migration from the Atlantic to the Aegean from autumn to spring. To catch these migratory, off-shore fish demanded some kind of boat, and either a hook and line or, as some scholars suggest, large, strong nets with the accompanying ropes, floats, and weights that were required.

FISHING PRACTICES

From a hook and line to the precise choreographed maneuvers required to set the multiple nets of a tonnara, tuna were fished in antiquity using a variety of techniques. Effective hooks and gorges were made throughout history from stone, bone, horn, sea shells, and wood. Literary sources suggest that the hook and line was the most popular fishing method during the Classical Period. T.W. Gallant discovered that ancient authors make reference to 35 fish species, of which 28 were caught by hook and line and

63 Rose (supra n. 36) 434.
64 Wheeler and Jones (supra n. 5) 36.
65 Wheeler and Jones (supra n. 5) 36, and J.D. Evans and Colin Renfrew, Excavations at Saliagos (Oxford 1968) 78.
15 by this manner exclusively.67 A fisherman’s tackle box was equipped with a variety of fishhooks which were used to catch specific types of fish; short shanked and rounded for bonito and grey mullet, long shanked for sharks and albacore, and unbarbed for mackerel.68 After the appropriate hook was chosen, a fisherman fixed the hook to a horse hair leader assembly which also depended on the type of fish desired.69 A leader is a short length of line where the hook and fish weight configuration are assembled and then attached to the main line held by the fisherman. Thus, for bottom dwelling species such as sea bream, a fish weight is tied to the end of a flax main line and a leader or leaders are then tied to the main line some distance above the weight. For big fish, horse hair leaders were abandoned in favor of all flax line which was strong enough to land tuna and swordfish.70

Rod and line and hand-lining were the methods of line fishing utilized by Classical fishermen. Rod fishing for tuna, a technique still practiced by commercial fishermen, does not appear in ancient literary sources.71 Hand-lining, as the name implies, refers to a fishing technique where the hands hold the fishing line directly. Whereas we would think that only small fish were landed this way, literary evidence

68Gallant (supra n. 67) 14.
70Gallant (supra n. 67) 15.
71Gallant (supra n. 67) 14-5.
states that fishermen hauled massive tuna, swordfish, and shark from the depths by hand. 72

Oppian described hand-lining for tuna with the same affection and reverence reminiscent of Ernest Hemingway’s portrayal of Santiago in *The Old Man and the Sea*. Oppian writes:

Thereupon you will see the valor of both, such struggle there is as man and captive fish contend. His strong arms and brows and shoulders and the sinews of his neck and ankles swell with might and strain with valor; while the fish, chafing with pain, makes a fight, pulling against the pulling fisher, striving to dive into the sea, raging incontinently... Then the fisher on the stern is dragged bodily backward by the rush of the fish, and the line whistles, and the blood drips from his torn hand, but he relaxes not the grievous contest. 73

Furthermore, Aelian and Oppian’s portrayals of tuna fishing operations were almost identical to those practiced in underdeveloped countries such as the Maldives, Lakshadweep Islands, and Sri Lanka. Examples of these similarities include the use of boats, baited hooks, chumming with bait to attract the lead tuna to the boat so that the rest of the shoal will follow the leader, and smacking the water with oars to feign the boiling sea that accompanies a tuna’s aggressive surface feeding behavior (fig. 6). 74

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72 Gallant (supra n. 67) 15.
Fig. 5
Chumming with live bait. The two fishermen squatting either side of the rudder and holding scoops, ready to splash water, while the man standing amidships holds a small scoop-net with live bait for chumming. M Ben Yami, *Tuna Fishing with Pole and Line* (Kent 1980) 123.

Unfortunately, however, in these detailed accounts illustrating the romantic battle between tuna and fisherman, as well as the realistic comparisons which can be drawn to contemporary tuna hunters, the authors failed to depict any post-harvest activities once fish are bought on board. Modern hook and line tuna fisheries in the countries mentioned above neither gut nor ice their harvest on board, but rather, they bring fish to harbor to be sold within a few hours of being caught. They simply store the tuna in the shade and splash water on them to keep them fresh and clean.75 Tahitian fishermen on the other hand, who also sell their fish the same day they are caught, eviscerate and stack the tuna in racks.76 These contemporary examples show that fisherman working in tropical and subtropical environments similar to the Aegean are able to catch and sell fresh tuna with little or no ship board processing.

75 Ben-Yami (supra n. 74) 137-8.
76 Ben-Yami (supra n. 74) 138.
Oppian described gill nets as one of the net types used for tuna.\textsuperscript{77} A gill net is unique in that the mesh size of a net corresponds to the size of fish desired. If a fisherman wants a medium sized fish, the mesh must be large enough for a fish to fit in past the gills, allowing the opercula to become stuck. Pressure placed on a fish’s throat by the mesh causes the gills to open and as it tries to back out, the gills become entangled in the net.\textsuperscript{78} Oppian stated that a gill net was set up perpendicular to the shoreline. When a shoal swam close by, boats surrounded the fish and smacked their oars on top of the water to scare the tuna in the direction of the net. The gill net ensnared the fish and was then pulled to shore.\textsuperscript{79} Though an effective method for catching many fish, the \textit{tonnara}’s size and superior capture technique overshadowed the gill net’s success.\textsuperscript{80}

The \textit{tonnara} depicted by Oppian and Aelian is more of a fishing technique than a type of net. When tuna began their migration in April, a tuna lookout was stationed on a hill or on a high wooden watchtower projecting from land which resembled a heavy-duty ladder with a chair fixed on top.\textsuperscript{81}

\textsuperscript{77}Oppian (supra n. 73) 4.562-92.
\textsuperscript{78}Andres von Brandt, \textit{Fish Catching Methods of the World} (London 1972) 204.
\textsuperscript{79}Oppian (supra n. 73) 4.562-74.
\textsuperscript{80}Gallant (supra n. 67) 21.
\textsuperscript{81}See Oppian (supra n. 73) 3.636-7 for reference to the tower on the hill, and Gallant (supra n. 67) 22 for reference to the ladder.
Fishermen positioned lookouts in areas where tuna were known to pass close to shore. Upon spotting an oncoming shoal, the lookout summoned his comrades into their skiffs and sent them to the best position to intercept the approaching tuna. Each boat carried a section of seine net. A seine is constructed to contain fish rather than entangle tuna within its mesh. On the lookouts order, a section of net was set perpendicular to the shore. A second section, situated at the end of the first net and running parallel to the shore was shot to form an open ended box. After the tuna entered the open end, "pouring in without end, so long as they [fishermen] desire and as the net can receive the throng of them," a third section placed slack at the opening of the tonnara was brought to shore by a boat or line held by the lookout himself to prevent the tuna from

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82 Oppian (supra n. 73) 3.637-9.
83 Von Brandt (supra n. 78) 225.
Finally, the fish were hauled to shore in the manner of a beach seine where the tuna were clubbed and speared to death (fig. 2). Thus, the next section of this paper focuses on the materials available to fishermen for the manufacturing of fishing lines, and, more specifically for fishnets during the Upper Mesolithic in Greece.

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84 Oppian (supra n. 73) 3.645-7.
85 Aelian (supra n. 74) 15.5 and Oppian (supra n. 73) 3.648.
86 Rose (supra n. 36) 435.
CHAPTER VI

NET MATERIALS

Cotton must be excluded from the list of possible fishnet materials during the Mesolithic at Franchthi due to a discrepancy in chronology. Cotton first appeared sometime during the 3rd millennium B.C. in excavation levels at the subcontinental Indian sites of Mohenjo Daro and Harappa.\(^{87}\) It then took almost two thousand years for cotton to make its way across Arabia to Egypt by the 8th century B.C., before it finally emerged during the early Classical period in the Aegean.\(^{88}\) This evidence eliminates cotton as a contending fiber for all prehistoric fishnets.

A similar situation exists for hemp, although it is more complex. Unlike cotton, there is evidence for hemp in Europe during the Neolithic period, although not in the Aegean region. Hemp seeds have been found in Neolithic contexts of the Bandkeramik culture in Germany which date to 5500-4500 B.C., and impressions of hemp seeds in the floor from a house of the Tripolye culture in the Ukraine date to 5300-3500 B.C.\(^{89}\) Even though evidence for hemp exists in the Neolithic, it is restricted to northern European sites: Germany, Austria, Switzerland, Romania and the Ukraine.\(^{90}\) Hemp did not make an appearance in the Aegean until the 5th century BC, as described by Herodotus, who spoke of the Thracians having hemp and suggested indirectly that it did not exist in

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\(^{88}\) Barber (supra n. 87) 33.
\(^{89}\) Barber (supra n. 87) 16-17.
\(^{90}\) Barber (supra n. 87) 18.
Greece. Thus, hemp must also be dismissed as a viable net material, which is unfortunate due to its strength and resistance to rot in salt water.

One vegetable fiber that does fit the chronology is flax, and yet again, it too has characteristics affecting its value as a material for nets and lines. There are difficulties in presentation and interpretation of flax in the archaeological record. Flax is the plant fiber from which linen is made. Its domesticated form, *Linum usitatissimum*, comes from the wild variety *Linum biennia*. It is thought to have originated in the steppes of Iraq and Kurdistan, and eventually spread throughout most of Europe. Archaeological remains from Çayönü Tepesi provide evidence of flax seeds which date to 7000 B.C., and linen cloth dated to the 5th millennium B.C. was present at Çatal Hüyük. It is then thought to have spread to the rest of Europe and Egypt. A unique quality of flax, which enhanced its value, is that it can be used in two ways, both for its fibers and for its oil-bearing linseeds. However, when reviewing the archaeological record, the difficulty lies in distinguishing whether flax was domesticated for its seeds, its fibers, or both. If linseeds are not found, it could mean that the flax was harvested early in the growing season before seeds could form. This immature flax offers a fine, pale fiber excellent for cloth. Conversely, if flax is harvested after seeds have formed, the fiber is coarse and strong. Thus, theoretically, if someone should desire a stronger flax fiber and waits to harvest the flax, he would also be able to exploit the seeds.

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91 Herodotus, 4.74.
92 M. David Potter and Bernard P. Corbman, *Fiber to Fabric* (New York 1954) 290, and Barber (supra n. 87) 15.
93 Barber (supra n. 87) 11, n. 2, 12.
94 Barber (supra n. 87) 11-15.
such evidence of this practice in Greece. In fact, Jane Renfrew did a survey of all plant
remains in Greece, from the Early Neolithic to the Late Bronze Age, and discovered a
total of only 200 linseeds have been found, all of which came from the Early Bronze
Age levels at Lerna.95 Due to this gap in the Neolithic archaeological record, it is
necessary to switch to later written records provided by Linear B tablets, from the 13th
century B.C., and Homer from the 8th century B.C., to find evidence of the use of flax.

Even though Linear B tablets from Knossos and Pylos describe the mass
production of linen cloth, it was Homer who first mentioned flax, metaphorically, as net
material.96 In the Iliad 5, line 487, Sarpedon warns Hector to rally his men, "...So that
somehow you might not become, like being caught in a mesh net of all-catching flax,
spoil and prey to hostile men." Homer's reference to the use of flax for nets, however, is
helpful and limited at the same time, because the metaphor fails to compare the men to
fish. In other words, we have no idea what animal Sarpedon is implying, or whether it is
from a terrestrial or marine environment. Furthermore, in the Odyssey, after the suitors
have been slaughtered, a metaphor compares the bleeding dead bodies of the suitors with
those of dead fish caught in a net and left on the beach to die.97 This metaphor makes
the connection between fish and nets but lacks a description of the net's material. How
can we then interpret the evidence of flax nets presented by Homer? Although he never

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95 Jane M. Renfrew, "Early Agriculture in Melos," in Colin Renfrew and Malcolm Wagstaff eds.,
96 For information about textiles in Linear B tablets, see John T. Killen, "The Textile Industries at
Pylos and Knosos," in Cynthia W. Shelmerdine and Thomas G. Palaima eds., Pylos Comes Alive:
Industry and Administration in a Mycenaean Palace (New York 1984) 50, and references to fishing in
Homer, see William Radcliffe, Fishing from the Earliest Times (London 1921) 76-77.
97 Hom. Od. 22.384-86, and Radcliffe (supra n. 96) 76.
mentions flax and fishnets in the same context, the use of metaphor might be helpful. As Radcliffe points out, the purpose of the Homeric metaphor is to compare something unfamiliar with something familiar.98 Thus we might argue that the audience listening to these epics knew that when the rhapsode sang of nets of flax, they understood that the comparison was between men and fish, or that when men were being caught like fish, the nets doing the catching were made of flax. Whether or not the latter is a valid conclusion, we can glean from Homer that flax nets were used to catch animals, and possibly fish. Literary references aside, flax has important physical qualities which make it good choice for fishnets.

Flax shares many qualities with hemp, although it is weaker, less resistant to rot in salt water, and is unable to stretch.99 A flax fiber is made up of thin cells two to four centimeters long which connect end to end to form long strands, cohering by a series of colloidal substances. The assembled collection of naturally glued cells gives linen fabrics remarkable strength. As a result of its natural structure, flax is not elastic and stretches only one twenty-fifth of its original length before the fiber breaks.100 This quality is ideal for fishnets, however, because excessive stretching of the net material would allow the once captured fish to squeeze through the mesh. The problems with using flax for fishnets are related to size and maintenance. Flax nets are heavy and hard to manage when they are large and they must be tanned every three months in order to

98Radcliffe (supra n. 96) 74.
99For the different strengths of hemp and flax, see Jean Boudriot, The Seventy-Four Gun Ship: Vol. III (Paris 1987) 64, where he discusses composite sails made from both hemp and flax, and describes how stronger hemp threads ended up cutting those made of flax.
100Barber (supra n. 87) 21.
prevent the replacement of the entire net.\textsuperscript{101} Finally, although flax was used in Classical
times, there is no evidence of its existence in the Aegean until the Bronze Age.

In contrast, animal fibers have a better chance of being applied for fishnets than
any of the vegetable fibers. I will begin the discussion of animal fibers by briefly
reviewing silk and why it can be excluded from the list of raw materials for fishnets.
The earliest evidence for silk comes from the Yang-Shao Neolithic levels of Hsi-yin-
ts'un, and, like cotton, silk does not appear in the Aegean until the 5th century B.C.,
where it is found in the Athenian Kerameikos cemetery.\textsuperscript{102} Now I will switch to what I
feel are the most thought-provoking and problematic of the raw materials, sheep's wool
and goat hair.

The first domestication of sheep and the first exploitation of sheep for wool do
not necessarily coincide.\textsuperscript{103} The coat of a wild sheep from antiquity looked much
different than one of today. Fluffy, woolly white sheep exist because of selective
breeding specifically for wool. Originally, sheep were domesticated for their meat and
hides and later for their wool. Furthermore, it is difficult to detect when the transition
took place.\textsuperscript{104} As John F. Cherry points out, it is not until the Bronze Age, and most
definitely during the Mycenaean and Minoan palace periods, that large scale pastoralism
took place for the procurement of wool.\textsuperscript{105} This distinction between the different goals
of domestication relates to the type of wool that is produced. Fibers from sheep

\textsuperscript{101}Rose (supra n. 36) 178-179.
\textsuperscript{102}Barber (supra n. 87) 32-33.
\textsuperscript{103}Cherry (supra n. 47) 22.
\textsuperscript{104}Cherry (supra n. 47) 21-22.
domesticated for their wool are short and scaly. The scales allow the various wool fibers to join together and become felt when they are compressed or exposed to damp heat.

Different fibers snag each other and create an entangled mass of fibers. The kinkiness and random directions of the fibers is what gives wool a scratchy feel against the skin.\textsuperscript{106} Also, wool yarn is extremely elastic. It has been noted that wool fibers can stretch from one fourth to one half of their original length before breaking.\textsuperscript{107} As previously noted with non-elastic flax, elastic fibers appear to be at a disadvantage when used for fishnets because the threads would stretch under the force of a fish, enabling it to swim through the mesh. Also, wool fibers can absorb 50\% of their weight in water, and become extremely heavy and difficult to manipulate as a fishnet.\textsuperscript{108}

On the other hand, fibers from wild sheep differ considerably. Through experimental research with an ancestor of modern sheep, \textit{Ovis orientalis}, E.J.W. Barber discovered that hair fibers were non-elastic and brittle. When she attempted to spin them, the hairs continuously broke into smaller pieces, making it impossible for her to produce a viable thread.\textsuperscript{109} Thus, the weak and brittle nature of wild sheep hair appears to be an impractical choice for fishnets.

Finally, the last animal fiber to consider is goat hair. The basic structure of goat hair differs greatly from that of wool. While wool fiber is kinky and distinguished by

\textsuperscript{105}Cherry (supra n. 47) 25.
\textsuperscript{106}Barber (supra n. 87) 20.
\textsuperscript{107}Barber (supra n. 87) 21.
\textsuperscript{108}For the absorbency of wool, see Potter and Corbman (supra n. 92) 21, and for reference to wet wool and fishnets, see George F. Bass and G. Venetia Percy, "Fishing Gear," in George F. Bass et al. eds., \textit{Serge Limani:} Vol. I (forthcoming) ms. p. 40.
\textsuperscript{109}Barber (supra n. 87) 24, n. 8.
overlapping elastic scales, goat hair is “straight and comparatively inelastic,” and has
greater strength than wool.\textsuperscript{110} By using mohair as an example, goat hair does not shrink
or felt as easily as wool, and can be shorn either once a year with hairs 9 to 12 inches
long, or in warmer climates, twice a year with hairs 8 to 10 inches long.\textsuperscript{111} These
characteristics have secured the use of goat hair for nets from antiquity to the present. In
1989, an 83-year-old fisherman from Bodrum, Turkey explained to Bass that “goat hair
is best for the upper line of a net because its fibers are longer and more durable than
those of sheep's wool.”\textsuperscript{112} Of all the animal fibers discussed, goat hair fishnets have the
greatest potential of having been used during the Mesolithic. It is possible to present
evidence which shows that net makers might have exploited goat hair at Franchthi cave
before the introduction of domestication around 6000 B.C.

Wild goat, probably \textit{Capra ibex}, comprises 10% of the total bone weight during
the Final Paleolithic at Franchthi cave.\textsuperscript{113} It is clear that hunters killed these goats for
their meat and hides.\textsuperscript{114} The goats' hair might have had a secondary function as a net
material to catch small fish like sea bream during this period.\textsuperscript{115} Since the benefits of
goat hair have already been discussed, it is necessary to discuss evidence of tools needed
for making thread.

\textsuperscript{110}Potter and Corbman (supra n. 92) 173.
\textsuperscript{111}Potter and Corbman (supra n. 92) 173, 190.
\textsuperscript{112}Bass and Piercy (supra n. 108) ms. p. 40.
\textsuperscript{113}Payne (supra n. 20) 122.
\textsuperscript{114}Cherry (supra n. 47) 21-22.
\textsuperscript{115}Powell (supra n. 2) 50.
Before goat hair can be made into nets, it must first be spun into thread. Archaeological evidence for this practice usually appears in the form of a spindle whorl.\textsuperscript{116} A spindle whorl is a weight made from a heavy material, such as clay or stone, that is fastened to the end of a spindle, which is a shaft usually made of wood.\textsuperscript{117} The spindle is then flicked between the forefinger and thumb like a top. The momentum created by the spinning whorl facilitates faster and more efficient twisting of the natural fibers into thread. The twisted thread can then be wound tightly around the shaft of the spindle to keep it from unraveling.\textsuperscript{118} It is still possible to spin thread by using just the spindle itself. In fact, even during this century, spinners sometimes prefer a plain stick to a whorl-weighted spindle. An excellent example comes from ethnographic evidence reported by Grace M. Crowfoot. She observed that Trans-Jordanian women in the 1930s had used spindle whorls for wool, but when it came to spinning the short hair from goats, they preferred a \textit{plain} spindle.\textsuperscript{119} However, excavators found no spindle whorls at Franchthi cave.\textsuperscript{120} Furthermore, since the spindles are usually made of wood, or some other perishable material, their survival in the archaeological record is extremely rare.\textsuperscript{121} Even though the previous example illustrates that goat hair can be spun with a only a spindle, which may explain the absence of spinning tools from Franchthi cave, a

\textsuperscript{116}For the connection of spindle whorls and fishnets, see Bass and Piercy (supra n. 108) ms. pp. 49-50.
\textsuperscript{117}Similar finds are reported by Bass and Piercy (supra n. 108) ms. pp. 47-48.
\textsuperscript{118}Barber (supra n. 87) 43.
\textsuperscript{119}Barber (supra n. 87) 42-43.
\textsuperscript{121}Barber (supra n. 87) 51.
bigger problem exists in the Upper Mesolithic when large, strong nets were needed to capture the massive tuna. These levels lack both spinning tools and wild goat bones.122

Once more the argument leveled above concerning the dearth of spindle whorls due to poor preservation may be applied here, but the absence of goat bones warrants explanation if we are to put goat hair nets in the hands of Mesolithic tuna fishermen. One way to get around the lack of goat bones is to resurrect a previous argument concerning the exchange of raw materials by means of _emporia_. As mentioned above, by the Upper Mesolithic, boats had been traveling to acquire Melian obsidian for over 1000 years.123 In addition, when tuna bones first appear, there is also a distinct increase in the amount of Melian obsidian, indicating an intensification of seafaring.124 Bintliff takes this idea a step further and suggests that the obsidian was not procured by communities on an individual basis, but rather that a few journeys were made a year carrying large loads. The obsidian then “filtered through communities not directly involved with the trip—the amounts concerned would not necessarily constitute ‘trade’ but could be interchange of materials that usually cements social ties between adjacent communities.”125 Cherry agrees with Bintliff and corroborates this statement by stating:

The *seasonal complementarity* of settlements as a strategy of economic diversification and risk spreading, has been explored in greater detail by Bintliff. He pointed out, quite rightly, that such systems are not restricted to transhumant herding, but also encompass, for instance, summer trips to distant fishing grounds.126

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122 For artifacts, see Jacobsen (supra n. 120) 253-58, and for faunal remains, see Payne (supra n. 20) 124.
123 Cherry and Torrence (supra n. 35) 24.
124 Payne (supra n. 20) 128.
125 Bintliff (supra n. 6) 242.
126 Cherry (supra n. 47) 10.
Using this statement as a model, it is possible that due to an absence of wild goats in the surrounding area, the inhabitants of Franchthi cave acquired goat hair for net-making through an “interchange of materials” with other communities. Whether they exchanged obsidian, fish, or some other good that does not appear in the archaeological record for goat hair is immaterial for this argument. What is important is that even though the faunal remains of goats do not exist contemporaneously with tuna bones, the mechanisms to procure the raw material did.

So, the next logical step would be to examine what happens after 6000 B.C. when these mechanisms for the procurement of goat hair are no longer necessary due to a ubiquitous emergence of domesticated goats, as well as sheep, throughout the Aegean. Even though this question is beyond the scope of this thesis, a unique problem does arise from an inquiry of that kind. If we assume that goat hair continued to play an important role as a fishnet material during this shift in the faunal record from wild game to domestic goats and sheep, then the similarities in the bones of goats (*Capra hircus*) and sheep (*Ovis aries*) would make such an assumption impossible.

More specifically, the importance of goat hair cannot be determined when the animal skeleton producing the hair is undetermined. Faunal reports from the Aegean illustrate the difficulty in distinguishing between *Capra hircus* and *Ovis aries* as evident from the Neolithic sites at Achilleion, Franchthi, Paradeisos, and Sitagroi (table 2):

127 See Cherry (supra n. 47) 6, for dates concerning the domestication of animals in the Aegean.
### Table 2
Ovis/Capra identification from archaeological sites in Greece.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Ovis aries</th>
<th>Capra hircus</th>
<th>Ovis/Capra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilleion</td>
<td></td>
<td></td>
<td>5,811</td>
</tr>
<tr>
<td></td>
<td>MNI</td>
<td></td>
<td>312</td>
</tr>
<tr>
<td>Franchthi</td>
<td></td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td>% of total bone weight.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panagia</td>
<td>22</td>
<td>20</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>2.2%</td>
<td>1.2%</td>
<td>44.1%</td>
</tr>
<tr>
<td></td>
<td>% of total bone fragments.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitagroi</td>
<td>1650</td>
<td>376</td>
<td>12,920</td>
</tr>
<tr>
<td></td>
<td>MNI</td>
<td></td>
<td>1114</td>
</tr>
</tbody>
</table>

As the above data show, the combination of the two taxa *Ovis/Capra* dominates the data profile. Even in the two examples where species has been determined, there is a disproportionate number of *Ovis/Capra*. Until researchers develop more precise methods that will separate the *Ovis/Capra* grouping, taxon specific questions will have to seek answers through other means. Thus regardless of its use throughout antiquity and its performance advantages, to argue convincingly for the existence of goat hair

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130 Payne (supra n. 4) 129.
fishnets requires better evidence such as faunal remains, weaving tools, and, of course, an actual net.

Unlike the data available for goat hair, a recent discovery of vegetable fiber weaving from the Czech Republic provides a more likely scenario. At the Late Paleolithic base camp site of Pavlov I, dated between 25,000 and 22,000 B.C., four fragments of fired clay display negative impressions of flexible interlaced basketry or textiles make this site “...the earliest fiber based technology in the world.”

Researchers have been unable to distinguish whether impressions represent a textile, a term used only for flexible cloth or fabric, or a basket, wherein weaving is accomplished without a loom. However, the fragments clearly display two-ply plant fibers twined, or twisted, together into cordage. This technique allows scientists to “confidently assume” that both string and rope were made and used by the inhabitants of Pavlov I.

As for the cord material, pollen analysis shows the bast fiber plant nettle, genus *Urtica*, which is not indigenous to mainland Greece, flourished in the area and has a long history as a weaving material.

The antiquity of cordage plays a crucial role in the reconstruction of fishing equipment. Such evidence facilitates a wide range of potential tackle from fishing line to nets. If we extrapolate that the inhabitants of Franchthi cave manufactured various types of cord like those found at Pavlov I 14,000 years earlier, it gives Mesolithic

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134 Adovasio et al. (supra n. 133) 530.

135 Adovasio et al. (supra n. 133) 531.
fishermen a basic technology that enables them to make a variety of fishing gear and techniques possible. The material used to construct the tackle remains allusive. It will be necessary for archaeologists to look for the remains of alternative resources such as tree bark, vegetable fibers, grass, straw, or leather. For example, in the Pacific Northwestern Indians made fishing lines out of whale sinew, seaweed, and cedar bark that were strong enough to land 90 kg halibut. Thus, all possible resources need to be considered to determine what material was used in Mesolithic Greece.

\[136\] See Adovasio et al. (supra n. 133) 531-2 for pollen analysis and Barber (supra n. 87) 51 for availability of nettle in Greece.

\[137\] Evans and Renfrew (supra n. 65) 80.

CHAPTER VII

PRESERVATION

To preserve fish is a difficult task. Even today with the use of refrigeration and ice, post harvest loss is 35%, or 25 million tons of the total of the fish caught around the world. In developing countries, post harvest loss is 50%.139 The reason for this high loss can be attributed to the fact that all fish carry bacteria and enzymes which promote rotting after death. Furthermore, all fish whose tissues contain a high oil content, such as tuna, have an added disadvantage; their flesh becomes oxidized and rancid more quickly when exposed to air or when fishermen fail to bleed their catch.140 Bleeding a tuna, usually by cutting off the head or tail before rigor mortis sets in, allows for highly oxygenated blood to flow out of the fish. If the blood remains within the muscle tissue, the flesh will oxidize and putrefy at an accelerated rate.141 These chemical and physiological occurrences required prehistoric tuna fishermen to preserve their catch as soon as possible.142

A tuna’s seasonal migration is accompanied by extensive physiological change. In spring, tuna travel from the Atlantic into the Aegean Sea in order to spawn and return in autumn.143 Tuna normally inhabit the shallower water of the continental shelf where

139Board on Science and Technology (supra n. 15) 142.
140Frederick W. Wheaton and Thomas B. Lawson, Processing Aquatic Food Products (New York 1985) 107.
141Mayer and Ward (supra n. 16) 4-5.
142Powell (supra n. 2) 33.
they feed on zooplankton, except during migration when they occupy deeper water.\textsuperscript{144} This migration is marked by a significant increase in physical activity, especially feeding.

Not only do the fish need to fuel up for their long journey, but they must also eat to increase energy reserves in their muscle tissue prior to spawning. This behavior is due to the fact that when tuna spawn, they starve themselves and transfer their stored energy from the muscles to the gonads to facilitate gamete production.\textsuperscript{145} By the end of spawning season the flesh is almost completely drained of fat, protein, and carbohydrates. Modern fishermen avoid harvesting during this season because the quality of the meat is so poor.\textsuperscript{146} This fact shows the relationship between the feeding period of tuna migration and its influence on physiology.

As mentioned above, prior to spawning tuna are constantly filling their stomachs in order to load their tissues with fat, protein, and carbohydrates. A tuna digests its food by secreting powerful enzymes from glands located around the stomach.\textsuperscript{147} As soon as a fish dies, however, an interesting event takes place wherein the fish begins to digest itself; fishermen refer to this metabolic process as belly burn. High enzyme levels within the stomach and intestines due to active, heavy feeding cause this condition.\textsuperscript{148} Following death, these enzymes penetrate out of the gut walls and begin to consume the

\textsuperscript{144}Powell (supra n. 2) 33.
\textsuperscript{145}Wheaton and Lawson (supra n. 140) 108, 229.
\textsuperscript{146}Wheaton and Lawson (supra n. 140) 229.
\textsuperscript{147}S.A. Beatty and H. Fougère, \textit{The Processing of Dried Salted Fish} (Ottawa 1957) 2.
flesh surrounding the digestive tract. Modern fishermen must take precautions to limit the effects of belly burn because it discolors and taints the flesh, which lowers its quality and market value.

By gutting and controlling the temperature of their catch, a fisherman can limit damage caused by the enzymes. To eviscerate a fish immediately after it is pulled from the sea stops enzymes before they have a chance to eat away the flesh. Similarly, by lowering the body temperature of a fish to below freezing, it is possible to halt the digestive process. Due to limited technology, however, freezing was not an option until the 20th century when the use of refrigeration and ice became widespread. In antiquity, a fishermen’s main defense against belly burn was to use fishing practices which narrowed the time between when a fish dies and when it is gutted.

Along with enzymes in the digestive tract, bacteria also affect the freshness of fish. A healthy fish has bacteria throughout its body which thrive in the slime on its skin and internal organs such as the intestines. The immune system of a live fish can normally fight off these bacteria. Of course when the fish dies it can no longer fight off the microbe attack. As a result, the fish begins to spoil and decay. The rate of this degradation depends on ambient air temperature and the number of bacteria present.

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149 Beatty and Fougère (supra n. 147) 2.
150 Wheaton and Lawson (supra n. 140) 237.
151 Beatty and Fougère (supra n. 147) 2.
152 Wheaton and Lawson (supra n. 140) 237.
153 Wheaton and Lawson (supra n. 140) 234.
154 Wheaton and Lawson (supra n. 140) 235.
within and on a fish when it dies.\textsuperscript{155} If air temperature is between 18° to 21° C, bacteria will double in number every thirty minutes. Thus one bacterium will reproduce into 4,000 in six hours, 16,000,000 in twelve hours, 268,000,000 in fourteen hours, and 4 billion in sixteen hours.\textsuperscript{156} The three types of bacteria which lead to spoilage are \textit{Pseudomonas}, \textit{Archromobacter}, and \textit{Flavobacterium} and are found in the slime and the entrails. These bacteria are all capable of reproducing in large numbers in temperatures above 0°C.\textsuperscript{157} As mentioned earlier, refrigeration did not exist, so ancients exploited other methods of preservation to kill off these bacteria.

\textbf{SALT PRESERVATION}

Salt concentrations over 15% by weight of green fish will eliminate spoiling bacteria. In practical terms, 100 kg of tuna required in excess of 15 kg of salt.\textsuperscript{158} When the correct amount of salt is added to fish, it draws out the water within the fish which dissolves the salt and creates a brine around the animal.\textsuperscript{159} Fish containing large amounts of water can transfer water with salt easily. Cod which are almost 80% water can be salted and preserved whole, while tuna and other fish with a high oil content

\textsuperscript{155}Wheaton and Lawson (supra n. 140) 107-8.
\textsuperscript{156}Wheaton and Lawson (supra n. 140) 235.
\textsuperscript{157}Wheaton and Lawson (supra n. 140) 236.
\textsuperscript{158}Beatty and Fougère (supra n. 147) 11.
\textsuperscript{159}Beatty and Fougère (supra n. 147) 11.
cannot.\textsuperscript{160} The high oil and fat content of tuna blocks the salt from penetrating into the flesh making preservation by salt alone difficult.\textsuperscript{161}

A better method for preserving tuna with salt is pickling or brine salting. Brine salting consists of water with a high concentration of salt, 30 kg of salt for a 100 kg of fish.\textsuperscript{162} Tuna immersed in brine will have a better chance of being preserved than dry salting because fish are submerged in a oxygen-poor environment.\textsuperscript{163} If tuna are kept below the surface of the brine, this anaerobic condition kills bacteria and slows rancidity which occurs when fatty tuna flesh comes in contact with oxygen.\textsuperscript{164} What is unclear is whether or not the inhabitants of Franchthi Cave knew the preserving qualities of salt and had access to the mineral.

Van Andel and Runnels suggest that salt might have been traded for other raw materials, such as andesite millstones from Aigina, during the Neolithic and possibly the Mesolithic.\textsuperscript{165} They base this statement on historical evidence for procurement and trade of salt gathered from shallow lagoons near Franchthi cave.\textsuperscript{166} Furthermore, salted fish became a potential commodity by the end of the Neolithic.\textsuperscript{167} In other words, Mesolithic inhabitants had access to salt, but there is only indirect evidence insinuating

\textsuperscript{160}Beatty and Fougère (supra n. 147) 11
\textsuperscript{161}International Labour Office, the Food and Agriculture Organisation and the United Nations Environment Programme, \textit{Small-Scale Processing of Fish} (Geneva 1982) 2.
\textsuperscript{163}Doré (supra n. 162) 149.
\textsuperscript{164}Hans Henrik Huss, \textit{Fresh Fish—Quality and Quality Changes} (Rome 1988) 17-8 and Doré (supra n. 162) 149.
\textsuperscript{165}Van Andel and Runnels (supra n. 7) 236.
\textsuperscript{166}Tjeerd H. van Andel and Curtis N. Runnels, \textit{Beyond the Acropolis} (Stanford 1987) 73.
\textsuperscript{167}Van Andel and Runnels (supra n. 7) 238.
its use. As will be discussed below, the best indicator for salt use stems from tuna's accelerated rate of decay requiring salt as the post-harvest preservation technique.

Tuna can also be preserved by fermentation. Fermented fish sauce is made by placing the whole fish, including the guts, gills, and blood, into a container. As mentioned above, salt is added to destroy unwanted bacteria.\textsuperscript{168} The powerful enzymes present in the digestive tract which cause belly burn as a result of aggressive feeding begin to break down the large molecules of the fish tissues into smaller ones.\textsuperscript{169} Once this process has taken place, lactic acid bacteria thrive on the remaining smaller molecules breaking them down even further.\textsuperscript{170} These bacteria which are found in the slime, \textit{Bacillus} and \textit{Micrococcus}, and in the stomach, \textit{Bacillus} and \textit{Clostridium} give the fish sauce its distinct bouquet and flavor.\textsuperscript{171} Due to the necessity for these bacteria in the fermentation process, an aseptic environment is preferred.\textsuperscript{172} The modern practices of evisceration and cleaning off the external slime to rid the fish of bacteria are counterproductive to fish sauce fermentation.\textsuperscript{173} After the tuna has fermented, all that is left is liquid, and a pile of bones at the bottom of the container.\textsuperscript{174} During the Mesolithic, however, no containers bearing tuna bones at the bottom have been found. It is possible to imagine, when taking the antiquity of cord technology into consideration,

\textsuperscript{169}Saisithi (supra n. 168) 114.
\textsuperscript{170}Saisithi (supra n. 168) 115.
\textsuperscript{171}See Wheaton and Lawson (supra n. 140) 236 for lists of bacteria and Saisithi (supra n. 168) 126 for bacteria and their flavor.
\textsuperscript{173}See Wheaton and Lawson (supra n. 140) for modern sanitation practices.
that watertight baskets served as receptacles. Such baskets are made of perishable materials and their survival is unlikely. Nevertheless, fermentation as a preservative technique should not be overlooked.

SMOKING

Smoking as a preservation method works well with oily, fatty fish such as salmon, herring, and tuna. It kills bacteria and dehydrates or dries the flesh which helps prevent mold growth and spoilage.\textsuperscript{175} Any moisture remaining in the flesh after processing dramatically shortens its shelf-life. The smoked fish usually seen nowadays at the local supermarket tend to be moist as a result of being light cured or cold smoked.\textsuperscript{176} This technique does little to preserve the fish and is only meant to provide flavor. Most smoked salmon, sometimes referred to as lox, is a product of cold smoking which requires the smoke’s temperature to remain below 29°C.\textsuperscript{177} A fish smoked by this method becomes rotten at the same rate as a fresh fish. For preservation purposes, hot smoking techniques allow for the flesh to remain edible for many months.\textsuperscript{178}

Even with the high temperatures utilized, when used alone, hot smoking is usually unsuccessful in guarding against putrefaction. During the smoking process, many forms of non-sporulating bacteria are killed by heat (60°-110°C) and other substances within the smoke. After 4 to 12 hours of treatment, however, spores of

\textsuperscript{174}International Labour Office et al. (supra n. 161) 2.
\textsuperscript{175}Stewart (supra n. 138) 135.
\textsuperscript{176}Doré (supra n. 162) 169.
\textsuperscript{177}Doré (supra n. 162) 171.
\textsuperscript{178}Doré (supra n. 162) 169.
*Bacillus* can still survive.\(^{179}\) For this reason, fish are dry salted or brined to kill spoilage bacteria and then smoked. Salting also creates a glossy surface on the flesh, known as the pellicle.\(^{180}\) This outer skin protects and seals the meat when smoked. Thus, salting prior to smoking might have been a necessary step to secure fish for a later date.

In order for flesh to dehydrate and preserve properly, temperature and density of smoke must be controlled.\(^{181}\) At the beginning of the smoking process, heat needs to remain around 39°C so that the pellicle can harden. Excessive heat will cook the fish too quickly and cause the muscle tissue to separate and fall apart. Once the surface flesh becomes rigid, temperature and smoke density can be increased.\(^{182}\) Smoke density plays an important role especially with tuna due to the fact that wood smoke carries phenolic antioxidants which penetrate the pellicle and protect against rancidity.\(^{183}\) With an ability to gain over 90 kg of fat just during heavy feeding periods preservation by smoking would have been an excellent way for a Mesolithic fisherman to control a bluefin tuna’s tendency to oxidize and turn rancid quickly.\(^{184}\)

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\(^{179}\) Board on Science and Technology (supra n. 15) 155.

\(^{180}\) Doré (supra n. 162) 170.

\(^{181}\) Doré (supra n. 162) 171.

\(^{182}\) Doré (supra n. 162) 171.


\(^{184}\) Butler (supra n. 143) 235.
CHAPTER VIII
CONCLUSIONS

During the Final Paleolithic period when the first evidence of people sailing to Melos for obsidian appears, there are no data reflecting the type of vessel people boarded to traverse the prehistoric Aegean. Broodbank and Strasser’s colonization requirements and Anthony’s migration theory force us to rethink the types of craft that were built and sailed in the Aegean prior to the Neolithic. The combination of these two theories provides strong evidence for more sophisticated boats then previously thought. Most scholars believe the simplicity of the Mesolithic tool kit would make such hulls impossible to build. Ethnographic data of Chumash Indians, however, display how planked hulls can be constructed with similar tools. To put it another way, tools need not have a direct correlation with boat building technology during the Mesolithic; especially in light of the practical and theoretical observations mentioned earlier. If suitable boats for migration existed before the Neolithic, then we can argue that such boats were developed to serve the needs of Mesolithic sailors. These needs reflect at least 3000 years of voyaging to Melos and 1000 years of bluefin tuna fishing.

By using the data provided by fishing techniques, materials for tackle, tuna physiology and behavior, and preservation methods, a few narratives can be forwarded which suggest the benefits of various fishing practices in relationship to the data. The most likely capture methods for bluefin tuna are hook and line and fishnets.

Catching tuna with hook and line has advantages to other techniques. The antiquity of cordage from Pavlov I allows us to consider the potential use of fishing
lines Though important due to the weight and strength of bluefin tuna, the material employed to fabricate these lines is unknown. It is most likely that plant fibers were twined into thick lines capable resisting the pull of a large fish. The most important aspect of hook and line fishing is related to benefits in preservation.

When a fish is pulled to the boat with a hook and line, it is still alive. If fishermen fail to bleed a tuna, the highly oxygenated blood circulating within the fatty flesh will promote oxidation causing rancidity resulting in a dramatic loss of shelf-life. Blood can be easily removed by cutting off the head, extracting the gills, evisceration, or lopping off the tail. Due to Rose’s analysis stating that tuna bone specimens found at Franchthi cave suggest that fish were brought to the cave whole favors bleeding by gutting. Removal of entrails also prevents belly burn and contamination by bacteria living in the digestive tract. Once rigor mortis sets in, blood coagulates making removal impossible. In sum, by fishing with a hook and line, a fisherman has the opportunity to kill and bleed a tuna immediately. This initial post-harvest processing helps increase the effectiveness of other preservation methods. By taking steps to guard against spoiling and rancidity at an early stage before salting then smoking, fishermen better their chances of preserving the flesh for the long term.

The disadvantages of hook and line fishing are its inefficiency in catching a large number of fish at the same time. The amount of fish landed depends on the quantity of hooks in the water. As Oppian’s description of the chaos involved on board a boat when a tuna is hooked illustrates, it appears to be a difficult task to haul in multiple fish simultaneously. Also, by fishing with a hook and line, hunters cannot
benefit from the fact that tuna travel in densely populated shoals containing hundreds of animals. To catch part or all of a shoal rather than a single fish results in a huge increase in harvesting productivity.\textsuperscript{185} The best way to fish an entire school with the least amount of effort is use a net.

A net allows fishermen to land a massive amount of tuna in a short period of time. This jump in productivity, however, becomes a post-harvesting nightmare. The success of a long term preservation technique relies heavily on the speed in which a tuna undergoes post-harvest processing such as bleeding and evisceration. Due to the number of fish captured during netting, processing would occur at a much slower rate, thus having a direct affect on the quality of the flesh. For instance, when beach seining and the tonnara are practiced, tuna are netted and then brought to shore for slaughtering. If the tuna fail to receive immediate attention, factors which aggravate rancidity and spoiling, like air temperature and post mortem duration, begin to play a definitive role in the success of future preservation strategies.\textsuperscript{186} Decay is also exacerbated by a tuna's behavior upon being netted. When tuna are forced into the close confines of a net, they panic and fight to survive in a extremely tight space.\textsuperscript{187} This highly stressed state causes a bluefin tuna's high metabolic rate and body temperature to rise resulting in the build up of lactic acid. High levels of lactic acid within the muscle of a dead tuna induce the onset of rigor mortis.\textsuperscript{188} As mentioned above, after rigor mortis a fish can no longer be bleed. Therefore, not only does net


\textsuperscript{186}Mayer and Ward (supra n. 16) 4.
fishing delay post-harvest processing due to the large number of fish requiring
treatment, but it also cuts the amount time fishermen have to process their catch before
the beginning stages of decay.

Finally, even though there are some negative qualities related to netting, its
benefits in productivity make it the best method for catching tuna. Research conducted
by D. Gentry Steele and Barry W. Baker concerning mass predation of a species
provides an anthropological basis for the use of fishnets. Mass predation refers to a
hunting technique where "...several prey are killed during a hunting episode."189 Using
evidence dating to the Upper Paleolithic, they associate six human behavioral patterns
necessary in mass predation, four of them relate to this thesis: (1) food sharing; (2) tool
use; (3) delayed consumption of food; (4) transportation, storing, and preservation of
the surplus of the kill.190 Furthermore, in instances where humans have access to
species which herd or shoal and can be surrounded or driven, such as bluefin, they tend
practice mass predation.191 Thus, in the terms of the Mesolithic Aegean, fishing method
and preservation are not mutually exclusive. Evidence from Franchthi cave suggests
that shoaling bluefin tuna were caught with fishnets due to the human propensity for
mass predation and includes preservation for later consumption.

187Mayer and Ward (supra n. 16) 4.
188Mayer and Ward (supra n. 16) 4-5.
189Steele and Baker (supra n. 185) 17.
190Steele and Baker (supra n. 185) 25.
191Steele and Baker (supra n. 185) 26.
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