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Ancient Fishing Gear and Associated Artifacts from Underwater Explorations in Israel - A Comparative Study

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ABSTRACT: Underwater archaeological explorations along the Israeli coast have revealed fish remains, fishing gear, and auxiliary implements. These were recovered from submerged prehistoric villages, anchorages, harbors, fishing grounds, and shipwreck sites. Prehistoric fishing techniques included free-diving fishing and fishing by nets and hooks. A set of fishing gear recovered from a Roman shipwreck off the Carmel coast included netting tools, fishing hooks, lead sinkers, and auxiliary tools. The sinkers found in this wreck, some decorated, enabled the identification of cast net(s), passive standing nets and beach seines. A discovered set of artifacts used for fishing by light included cast net sinkers, a fishing spear, an iron fire basket and a sounding weight. Auxiliary implements found in Israel included sounding weights for fishing ground location, grapnels and rings for salvaging lost gear, and coral harvesting gear. Documents written by ancient authors and mosaics helped in identifying the recovered fishing artifacts.

KEYWORDS: FISHING, ISRAEL, PREHISTORY, PROTOHISTORY, CLASSICAL ANTIQUITY, FISHING GEAR, FISHING METHODS

RESUMEN: Prospecciones arqueológicas subacuáticas a lo largo del litoral israelí han evidenciado la existencia de restos de peces, aparejos pesqueros e implementos auxiliares asociados con la pesca. Todos ellos se recuperaron en poblados prehistóricos sumergidos, puertos, zonas de pesca, pecios y puntos de anclaje de navíos. Las técnicas pesqueras prehistóricas incluían la inmersión a pulmón y, sobre todo, el uso de redes y anzuelos. Un lote de aparejos recuperados en un pecio romano en la costa de Carmel incluía aparejos de enmalle, anzuelos, plomadas y otras herramientas auxiliares. Las plomadas recuperadas en este pecio, algunas de ellas decoradas, permitieron identificar la existencia de trasmallos, chinchorros de playa así como esparaveles. Un lote asociado de utensilios de uso pesquero para capturas con luz incluían un tridente, plomadas para trasmallos, un cesto de hierro para la hoguera y una plomada de tipo sonajero. Utensilios auxiliares hallados en Israel incluyen plomadas sonajero para la localización de las zonas de pesca, anillos y ganchos para recuperar aparejos perdidos y aparejos para la recolección de corales. Tanto los documentos escritos de los autores clásicos como de los mosaicos han servido de ayuda para identificar los utensilios de pesca recuperados.

PALABRAS CLAVE: PESCA, ISRAEL, PREHISTORIA, PROTOHISTORIA, ANTIGÜEDAD CLÁSICA, ARTES DE PESCA, MÉTODOS DE PESCA

INTRODUCTION

Since early prehistoric times humans were attracted to shores (Brandt, 1972). The border between land and water provided diverse and rich subsistence to coastal dwellers, much of it derived from fishing. Fishing methods can be classified into three major categories: 1) manual collection without tools; 2) passive fishing based on the use of natural and human-made devices that capture fish using natural fish mobility; and 3) active fishing, based on attacking aquatic creatures by human-made devices. Seas and inland waters in Israel are rich in archaeological remains left by ancient human cultures. These remains constitute material testimonies about activities conducted along these coasts during the past millennia. Such activities included shipping, trading, fishing, acts of war, etc. Starting from the middle of the 20th century, numerous underwater surveys and excavations were conducted along the Israeli coasts. Among the findings were shipwrecks, cargoes, remains of port and anchorages as well as submerged prehistoric settlements. These findings contribute to the understanding of ancient marine history, especially in Israel and in the eastern Mediterranean. This paper is based mostly on archaeologically derived artifacts discovered along the Mediterranean coast of Israel and along the shores of the Sea of Galilee. These artifacts include instruments used for fishing and procuring marine life and also auxiliary devices associated with such activities. Selected artifacts from the Mediterranean region will be used for comparative purposes. Ancient written sources and iconographic data will be used to support and back the conclusions derived from studying the functional artifacts. Three assemblages recovered off the Israeli coast have been used for reconstructing fishing technologies as integrated systems. These assemblages include the finds from a Roman shipwreck site containing sinkers, hooks, and netting tools; a Byzantine shipwreck at Dor yielding a complete gear of light fishing; and the finds from submerged prehistoric settlements off the Carmel coast, especially the Pre Pottery Neolithic site of Atlit-Yam.

ANCIENT AND TRADITIONAL FISHING METHODS

Fishing with bare hands

Shellfish can be easily collected in shallow water by hand or with simple, non-specific tools. This turned them into an important food source since prehistoric times (Colonese *et al*., 2010; Cortés *et al*., 2011). Mollusks, crustaceans, cephalopods, and echinoderms have been collected in the shallows since prehistoric times. Driving aquatic creatures into tide pools could have worked everywhere and digging in sandy beaches can yield acceptable numbers of clams and crabs. In sandy beaches, during the spring, turtle eggs can be collected and laying females captured. Such basic fishing methods are still being used by traditional artisan fishermen in the area. Generally, in traditional coastal communities, these foraging activities are relegated to women and children (Powell, 1996: 77).

Attractants

Aquatic creatures can often be collected by various kinds of attractants. These could be food and food imitations, or simply light and shade. The attracted creatures may be later caught manually or through other means.

Free-diving

Free-diving fishing without protecting the eyes limits visibility, and cold water in winter can expose a free-diver to hypothermia after ca. 15 minutes. A free-diver, however, can easily dive to a depth of a few meters and carry out various kinds of activities underwater. Powell (1996: 83-84) points out that free-diving is hard to identify in the archaeological record, as the only equipment that is needed is often restricted to a stone weight, a knife, and a basket. Local undressed stones that could have been used for buoyancy control of free divers are abundant on the sea bottom. Woven baskets usually decay and knives have many other uses. Archaeological and ethnological studies suggest that Neolithic coastal inhabitants, even without watercraft, expanded the list of their subsistence items through free diving. Free divers can collect fish and other sealife hidden in rock crevices or among seaweeds. In a sea rich in edible resources, a diver familiar with the underwater terrain may not only collect the amount of food sufficient for his subsistence but also support several family members. Free-diving fishing justifies the energy expended even in cold water.

Fish traps

Fishing with traps has an obvious advantage over nets, harpoons, and hooks for fish are not killed during the process. Unlike fishing with gill nets or lines and hooks that require a fast retrieval of the catch in order to avoid the decay or the devouring of the captured fish, a trap is left at sea for a few days. Fishing traps were used in the Levant until the first half of the 20th century (Hornell, 1935: 43, 102, 104) and are still used in the Sea of Galilee and the Red Sea (Grophit, 1991: 13). Iconographic evidence shows fishing with weir traps in Egypt during the Old Kingdom (Brewer & Friedman, 1989: 31-38). Traps that enable animals to enter but prevent them from escaping may often work without bait. Permanent trapping gear include standing nets leading fish to areas from where they cannot escape (i.e. the «killing chambers»). Such systems often cover large areas and are operated by cooperative communities.

Harpoon and bow and arrow

Early prehistoric hunters must have targeted aquatic forms in similar ways to terrestrial ones and fished with stone missiles and later with hafted missiles. Such missiles evolved on land into complex harpoons and later into bows and arrows. These offensive artifacts were used also to obtain aquatic creatures. In more evolved forms, such fishing systems are still used today.

Hooks

In early prehistory, humans may have invented the gorge to carry bait to be swallowed by fishes and other aquatic creatures. A line tied to the gorge enabled a fisherman to retrieve the animals that swallowed such gorge. Seemingly, the gorge evolved into the hook which can be conceived as a combination of a barbed, or barbless, spear and the gorge. Like the gorge, the hook is tied to a line that is used to collect the capture. The bait, added to the gorge or hook, could be food or just a device imitating food or an escaping fish. Often, such a hook with such an attractant was operated from a boat or from the beach. By tying the line to a pole, the fisherman extended the range of the baited hook. The single hook-and-line later evolved into a «long line» carrying branching lines with a baited hook at the end of each. The hooks were baited and the long line placed on the sea bottom or at midwater. At times, jars replaced hooks on a long line. Crabs and cephalopods looking for shelter entered the jars and were thus captured.

Nets

Fishing nets include coastal seines, cast nets, trammel nets, and gill nets. An early descriptive account for the use of fishing nets comes from the Old and Middle Kingdoms of Egypt (Brewer & Friedman, 1989: 31-38, 40-41). No hard archaeological evidence for the use of cast nets or coastal seines in prehistoric times, however, is yet available. Fishermen use nets both passively and actively. A net can be placed in the water and positioned permanently or temporarily in an area were fish are moving. Fish crossing such an obstacle get entangled and are picked up by a visiting fishermen or when the net is lifted. Another netting method is applied by fisherman on shore or on a boat by following a school of fish and, at an opportune moment, spreading the net, capturing the fish with it.

Standing nets: Such nets are set from boat or from shore. They are placed like a vertical wall, stabilized by floats on top and sinkers in the bottom (Stewart, 1981, 1982; Kuniholm, 1982). The net is kept in place by weight anchors and marked by floats, enabling the fisherman to collect entangled animals. Passive nets may be classified into nets with a single wall, termed gill nets, and nets with several walls termed entanglement nets (trammel nets). Fish trying to cross a gill net are caught by their gill covers. Entanglement nets are composed of three walls of mesh, one with small eyes hanging loose between two ones with larger eyes hanging tight. Fish passing the external net are caught in the loose middle net. When trying to escape, they pull the middle net, forming pockets in the opposite net in which they are captured. In both net types, the size of the fish caught is controlled by the mesh size.

Seines: Graphic depictions and later written descriptions from antiquity indicate that beach seines were one of the earliest forms of fishing nets. The beach seine is a moveable wall, constructed similarly to the gill net described above, but with a heavy foot rope that enables dragging.

One end of the net is fixed to the beach while the other is spread away from the beach and then back, thus forming a semi-circle. The surrounded fish are trapped between the beach and the net which is pulled to the beach, bringing the captured fish with it. Such fishing systems are always operated by a group of fishermen. More advanced forms of seines are dragged by two boats and may be operated away from the shore.

Cast nets: This type of net is applied by a single fisherman operating from the beach or a boat. The fisherman casts a circular net dexterously, spreading it over an area suspected to contain fish. The sinkers at the end of the net cause it to descend fast, trapping the fish in the falling cone of mesh. The net is then collected into a closed bag by built-in strings, bagging the fish in it.

Use of light and shade

Some aquatic creatures are attracted by light while others are attracted to areas lying in the shade. Fish thus attracted are captured by seines, gill nets, entanglement nets and cast nets or are speared with harpoons.

Fishing with poisons

Pre-modern and modern traditional fishermen use various kinds of poisons to capture fish. Most of these poisons are derived from local plants. Such a practice was recorded both in antiquity and in pre-modern Israel (Hornell, 1935; Avitsur, 1976).

Coastal pools Holding tanks

Prior to the invention of refrigeration, it was impossible to preserve fresh fish and other sea life out of the water. To overcome that limitation, quarried and built shallow ponds were constructed along the shore. At times, fish were grown or kept in such enclosures (Nun, 1964; Higginbotham, 1997; Marazano & Brizzi, 2009). These ponds were constantly supplied with fresh seawater by waves or tidal movements. The remnants of such human-made features along the coast indicate such fishing activities in the past.

ANCIENT FISHING TOOLS FROM ISRAEL

Fishing instruments recovered during excavations indicate that fishing on the Carmel Coast was practised since Paleolithic times (Van Neer *et al*. 2005). Traces of fishing activities (fish bones and fibers-nets?) were recovered at the Upper Paleolithic site of Ohalo II in the Sea of Galilee (Nadel *et al*. 1994).

Prehistoric fishing

The Levantine coast is the marine environment closest to the core areas where the Neolithic domestication of plants and animals started some 10,000 years ago. At some point, the Neolithic reached this coast and the agriculturalists/herders interacted with the coastal hunter/gatherers that were fishing in it. This interaction developed into a specific type of agro-pastoral-marine subsistence system, the Mediterranean fishing village. Such coastal subsistence system exploited both marine and land resources. Its adequate use facilitated a permanent settling. Exploitation of marine resources is documented from previous Levantine Pleistocene and Holocene sites but the contribution of marine resources in the Neolithic subsistence system was not fully understood until recently (Galili *et al.* 1993, 2005; Van Neer *et al.* 2005). This is partly due to the fact that coastal prehistoric settlements are currently submerged off the present-day coastline. Several such submerged settlements were exposed in recent decades off the Carmel coast due to sand quarrying and construction of marine structures (Wreschner, 1983; Galili *et al*., 1993). The submerged settlements belong to two cultural phases: the Pre-Pottery Neolithic C period, and the Late Pottery Neolithic Wadi Rabah culture. The submerged Pre-Pottery Neolithic C settlement of Atlit Yam is located 300 to 500 m offshore in the northern bay of Atlit, 10 km south of Haifa at water depths of 8-12 m (Figure 1) (Galili & Nir, 1993; Galili *et al*., 1993; Galili *et al*., 2005). The five Pottery Neolithic settlements are located on the northern Carmel coast, some 1-150 m offshore at water depths of 0-5 m. Underwater explorations revealed the foundations of rectangular structures, paved floors, ritual installations, storage and production installations, and water wells. Faunal and floral remains included domesticated and non-domesticated vegetation, wild and domesticated animals, as well as fish remains.

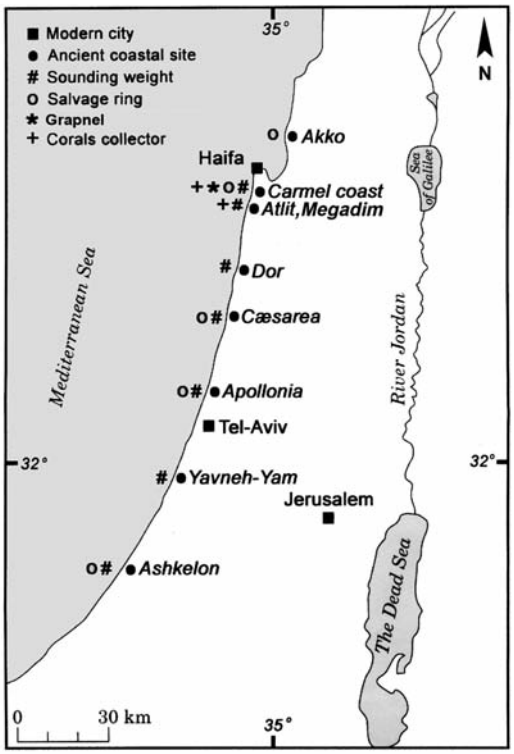

FIGURE 1
Location map.

Remains of at least 90 humans were found in both primary and secondary burial contexts.

Fishing techniques practiced in the submerged neolithic sites

Several active and passive fishing methods can be reconstructed from archaeological findings on submerged sites, mainly in Atlit -Yam (Galili *et al*., 2002a; Galili *et al*., 2004):

Fishing with nets: Dozens of perforated stones and pebbles found in these sites were probably used as net sinkers (Figure 2). In North America, small sinkers were used for foot-ropes and the bigger ones were used for anchoring net ends (Stewart, 1981: 78, 79, 91; 1982). Pointed bone spatulas and flat, wide, spatula fragments (gauges?) (Figure 3: A, B) may have been used for net-making (Stewart, 1981: 123; 1982). Fibers from plants found in these villages may have been used for producing fishing gear, such as lines, ropes, and

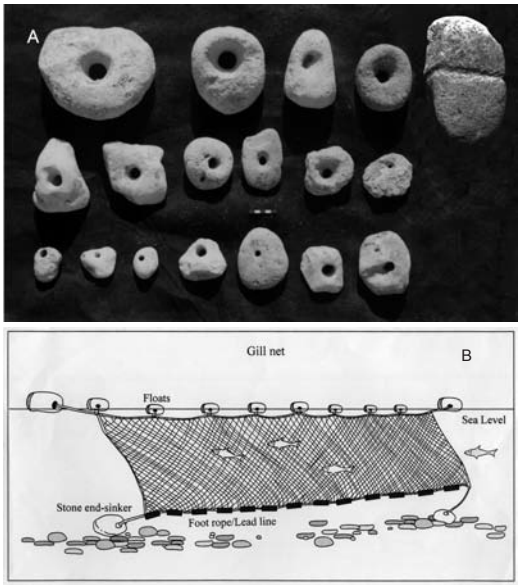

FIGURE 2
A) Fishing net sinkers from Atlit-Yam (J. Galili) and B) reconstruction of a net (after Stewart (1982: 86); S. Ben Yehuda).

nets, (Galili *et al*., 1993; Hartman, 1997). Unusual dental attrition of humans probably caused by continuous pulling of strings between the teeth was recorded in some of the Atlit-Yam skeletons (Hershkovitz & Galili, 1990). The body mass and standard length distribution of triggerfish (*Balistes carolinensis*) remains found in Atlit-Yam are typical of gill net capture (Zohar *et al*., 1994, 2001). Nets could have been set by either boats or rafts.

Fishing with hook and line: A broken fishing hook made of bone was recovered in well 11 at Atlit-Yam (Figure 3: C). Several 4-5 cm long bone points (Figure 3: D, E) may have served as barbs of composed leister spearheads or composed hooks (Stewart, 1981).

Free diving: Fifteen flint daggers or spearheads (8-14 cm long) were recovered. Four of these were found close to a concentration of thousands of fish bones (locus 10A). These tools may be associated with either spear-fishing or the gutting of fish (Galili *et al*., 1993).

Fishing instruments from historical periods

Hook and line fishing: Fishhooks are commonly found in ancient coastal settlements and at ship-

FIGURE 3

Bone tools from Atlit-Yam: A) pierced spatula used for net works, B) net gages C) fishing hook D) points used as barbs of composed hooks, E) a reconstruction of barbed wooden hook (J. Galili, S. Ben Yehuda).

wreck sites (Brinkhuizen, 1983; Parker, 1992: 330, 356, 440, 425).

Hooks from the Carmel coast shipwreck: More than 1,000 metal objects were recovered from a shipwreck site exposed by sea storms in 1990–1998 south of Haifa (Figure 1). These included netting tools, fishing hooks, lead fishing gear sinkers, and other fishing associated artifacts. The coins therein retrieved point to a shipwreck from the 3rd century CE (Ariel, 2010; Galili *et al*., 2010; Meshorer, 2010). A total of 33 bronze fishhooks of varied morphology were recovered (Figure 4). One of them had its shank partially enveloped in lead (Figure 5: A). Hooks can be

FIGURE 4

Bronze fishhooks from Haifa south beach site: A) flat tying end and B) with grooves on the shank to improve tying (T. Sagiv).

classified into those featuring barbed points and those without them, and also according to the line attachment method. No hooks had eyes, their ends being flattened (Figure 4: A) or tapered. Some had grooves at the tying heads and the shank to improve the line grip (Figure 4: B). The assemblage included mostly medium-sized hooks intended for catching fish weighing between 1 to 15 kg (Kotzer Adam, pers. com.). The lead added to the aforementioned small hook was intended to sink it when baited (Figure 5: A). Such lead weight hooks are sometimes used by modern fishermen (Figure 5: B). Two large hooks intended for deep-sea fishing of bottom dwellers or for capturing pelagic fish (tuna) were present in the assemblage. These hooks might have belonged to a crew member who occasionally engaged in fishing. Such practice is still common onboard local merchant ships and yachts. In ancient times, ships were wind-dependent and often anchored for an extended period of time, waiting for a favorable wind. Under such circumstances, maintaining assorted fishing gear onboard must have been commonplace. Fishhooks were likewise retrieved from a Late Bronze Age wreck from Ulu Burun (Parker, 1992: 439), and Roman wrecks have yielded sets of fishhooks in wooden boxes (Parker, 1992: 331) or in baskets (Parker, 1992: 444).

Fishing gear sinkers: In Israel fishing gear sinkers were recovered regularly during archaeological exploration in coastal settlements, graves, harbors, and shipwrecks. One of the first records was that of Petrie (1933, 1974) near Gaza. Until the mid-20th century fishing nets were made of highly perishable organic materials. When nets decayed all that remained were sinkers made of stone or metal. Lead is the commonest metal used

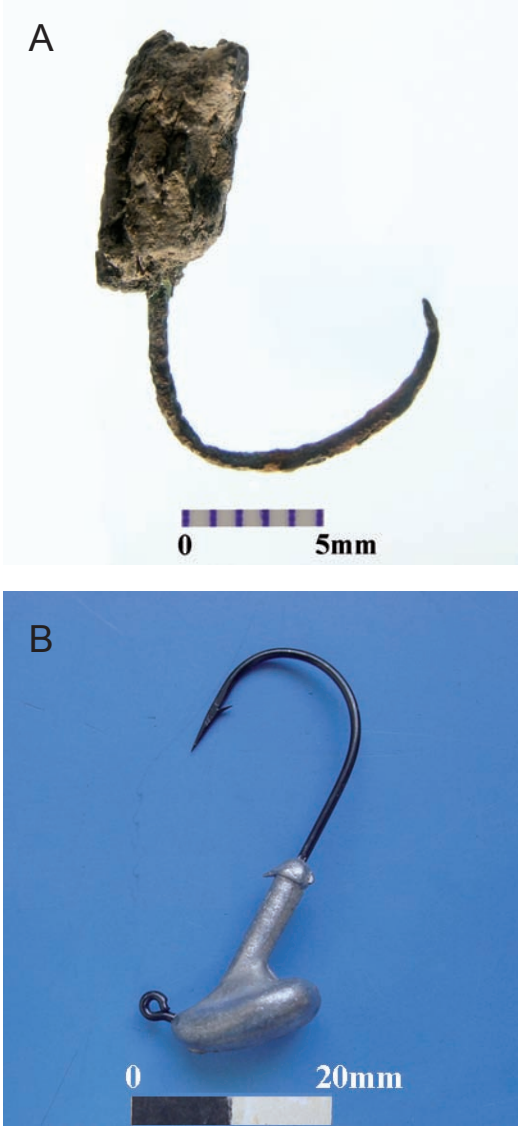

FIGURE 5

A) a bronze fishhook with lead envelope, B) a modern fish hook with attached lead sinker.

for such sinkers. Fishing gear sinkers from Israel have been classified on the basis of the type of material, shape, manufacturing mode, and functional properties as well as according to their probable use (Galili *et al*., 2002a).

Lead sinkers: Lead sinkers have been divided into two groups (Figure 6): **Group L1** - sinkers cast into the shape and form in which they were used (Figure 6: L1). Solid conic or pyramidal sinkers have a line attachment device on their top and are used for hook and line fishing (Figure 7); Tube-like net sinkers (Figure 8) cast in a mold with a core, are used for foot rope of a beach seine net. Solid rings are used for foot ropes of standing nets or certain types of cast nets (Figure 9). **Group L2** - sinkers formed mechanically by bending or folding (Figure 6: L2). These include rectangular strips bent into rings, sheets bent into tubes and folded rectangular pieces –the commonest type– bent over the lead line, forming a tightly bent «U»-shaped, «crimped» envelope. These sinkers are used for foot ropes of standing nets and the small ones for cast nets. **Group L3** - sinkers formed mechanically by rolling (Figure 6: L3).

Decoration on lead sinkers: Several types of decorations were observed on numerous folded rectangular lead sinkers (Figure 10). These included a) vertical lines parallel to the edges of the sinker; b) diagonal lines; c) inscriptions; d) drawn motifs (anchors, sea waves, fish bones); and e) geometrical shapes (dots, circles). The decorations were used to differentiate between the nets or the owners of fishing nets left at sea.

Lead sheets for producing sinkers: Sheets of raw material for producing sinkers were also recovered from the Carmel coast site (Galili *et al*., 2010; Galili *et al*., 2002a). Some sheets were cast to the right size whereas larger lead sheets could have been cut into the desired size, then bent.

Molds for casting lead sinkers: Molds for casting folded rectangular sinkers were found in Kastra and Shiqmona, two coastal villages located close to the Carmel coast, where numerous lead sinkers were found (Elgavish, 1994: fig. 13a; Zemer, 1999: fig. 13b) near Jaffa (Eitan Ayalon, pers. comm.). They were used for casting decorated rectangular sheets of lead intended for folded rectangular lead sinkers. A mold found in the Sea of Galilee (Figure 11) was used to cast sinkers for hook and line. Lead casting equipment has been found on the Yassi Ada wreck (Kuniholm, 1982).

Stone sinkers: Perforated and grooved stone sinkers were classified in one large group. In sinkers with more than one perforation, a wooden shaft was inserted into one of the holes to hold the ground like a composite stone anchor. Circumscribing crossed grooves or a single circumscribing groove may appear on stone sinkers. Most of these stone sinkers were used as end sinkers for nets. Such stones are seen on Egyptian drawings of

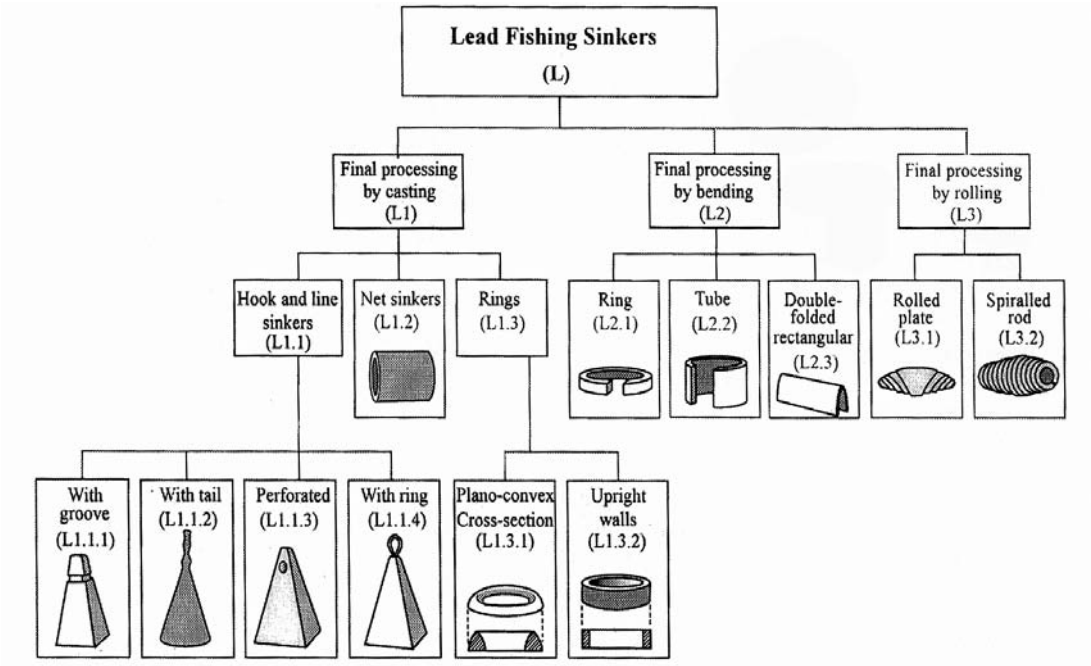

FIGURE 6
Classification of lead fishing sinkers from the Israeli coast (E. Galili).

FIGURE 7
Solid cast lead hook-and-line sinkers (T. Sagiv).

FIGURE 8
Solid lead tubes fishing sinkers (and a reconstruction) (T. Sagiv).

fishing scenes from the early dynasties (Brewer & Friedman, 1989: 38-46). Sinkers were also used to position traps (Sundstrom, 1957: 31-34; Stewart, 1981, 1982: 86), for lines carrying single hooks, and for long lines. Stone sinkers often have artificial or natural perforations or grooves. Numerous small, undressed, perforated stones were recovered along the shore of the Sea of Galilee (Nun, 1993). Most of them were naturally perforated stones which could have been picked up by fishermen to be used as net sinkers.

Dating and reconstructing ancient fishing-gear sinkers: Lead sinkers have not changed since antiquity. Thus dating them must be based on associated artifacts from a datable assemblage. Markings such as crosses, Greek, Roman or Arabic letters which are rarely found can also help in rough dating. Ancient fishing gear sinkers provide information on ancient fishing tackle. In Israel, groups

FIGURE 9

Reconstruction of lead rings used as net sinkers (T. Sagiv).

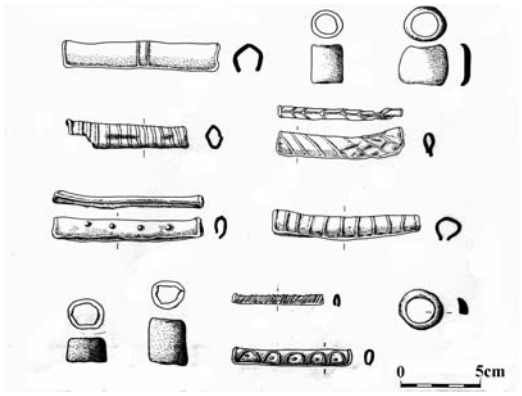

FIGURE 10

Decorated folded rectangular fishing sinkers (IAA).

FIGURE 11

A mold for casting hook and line sinkers from the Sea of Galilee (T. Sagiv).

of sinkers found together in graves may provide information about the structure of ancient nets. A «light net» from the Late Bronze strata at Tell el Ajjul, near Gaza, contained 17-18 lead sinkers (Petrie, 1933: 6). A total of 107 folded lead strip fishing-net sinkers were recovered from the Late Bronze Age Ulu Burun shipwreck (Pulak, 1988). If all these sinkers belonged to one net, it would be possible to reconstruct its length (Pulak, 1988). Powel (1996: 114-121) and Kuniholm (1982) both tried to reconstruct ancient fishing nets based on findings of sinkers.

The function of lead sinkers recovered from the Carmel coast wreckage site: Lead lines can be divided into three groups: 1) Working lines for pulling heavy loads, e.g., lead lines of beach seines and ring seines (Figure 8); and 2) Non-working lines not designed to withstand energetic strains in casting or retrieving the nets. The lead line of the cast net is an example of this group (Figure 12); and 3) Semi-working lines exist between the two stated functions. The diameter of the hole which once enclosed the lead line offers a clue as it fits the diameter of the lead line. In this way, the nature of the net, to which a given sinker belonged, may be deduced.

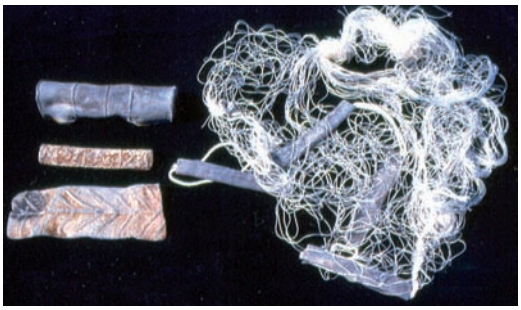

FIGURE 12

Modern cast net and ancient sinkers (T. Sagiv).

Sinkers used for Cast nets: In many sinkers, the diameter of the hole is about 1 mm. An ancient line of 1 mm diameter could not have served as a working lead line. Thus, on the coast of Israel a sinker with a hole of 1 mm +/-20% is assumed to have belonged to a cast net. An average modern cast net uses about 150-320 lead sinkers, having lengths of 35-50 mm each and a mass of 9-10 g each. The number and properties of the sinkers used on such nets must have been similar in the past.

Sinkers used for Beach seines, gill nets and trammel nets: The breaking strength of ropes from natural fibers increases rapidly with diameter (Knight, 1918; Rossnagel, 1950). A new line with a diameter of about 10 mm has a breaking strength of approximately 500 kg. Sinkers with such holes were used for beach seines and similar nets. Sinkers with holes of diameters between 2-8 mm could have belonged to gill nets and/or trammel nets. This is a very tentative reconstruction, but it at least offers a basis for discussion and experimentation.

Rings as fishing-gear sinkers: During the present study, several cast lead rings were recovered (Figure 9). The possibility that such rings were used as fishing-gear sinkers was considered. This type of fishing net-sinker is still used in Russia (Baranov, 1970: 80-81) and North America. Dozens of identical rings were found at *Caesarea* lying under water in a line at a distance of 25 cm from each other. This was similar to a case where a linear group of gill net sinkers was found underwater off Atlit. Most of the lead rings found along the Israeli coast represent the remnants of nets that were lost and rotted rather than brailing rings (Galili *et al*., 2002b; Galili *et al*., 2010). Finding of torn rings underwater suggests that these were connected to a lead line and were torn when caught under water and then pulled by force.

Netting Tools: The netting tool is an essential implement when manufacturing or mending nets. Its presence assures that a net-maker or a fisherman was in the vicinity. Netting tools, a few of them decorated, were discovered in Bronze Age Gaza (Petrie, 1917; 1933: Pl. XV), Roman-Byzantine Sarpeta in Lebanon (Prichard, 1988: 103, 217, 237, 279) and Jaffa (Nun, 1964: 190). They are expected to be found at onshore sites wherever ancient fishing activities took place. Present-day net-makers are using similar netting tools, characterized by a stem terminating by prongs on both ends (Figure 13). Scores of netting tools were recovered along the Israeli coast; six of them were recovered from the shipwreck assemblage south of Haifa associated with net weights and hooks. They were made of a copper alloy and all had stems that were round in cross-section, their heads being twisted onto two different planes. The sequence of net manufacture is reconstructed as follows. After the netting tool is loaded, the net-maker produces knots that create new eyes by dexterously manipulating the netting tool (Figure 14). Fishermen typically keep netting tools either on them or else

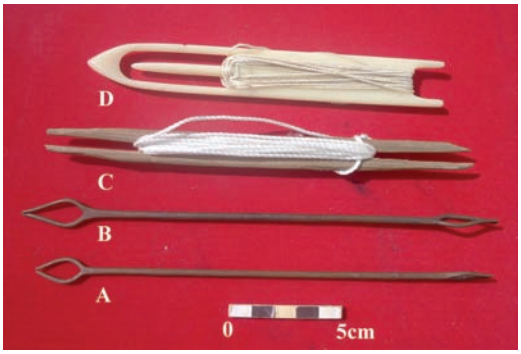

FIGURE 13
Modern traditional and ancient netting tools (J. Galili).

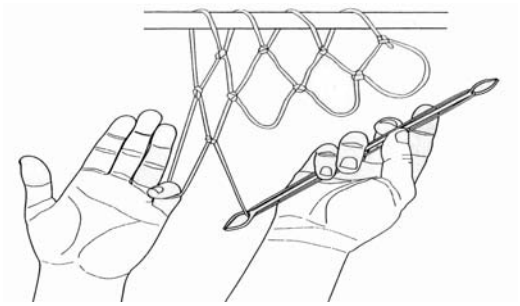

FIGURE 14
Using a netting tool (S. Ben Yehuda).

onboard the fishing vessel to rapidly mend torn nets. The netting tools from the Carmel coast site indicates that the mesh size of nets produced by them varied from 5 to 13 mm.

Remotely operated Auxiliary instruments used by Fishermen: Fishermen carry out numerous activities on the sea bed, thus recognizing sea-bottom features is essential. As a result of this, various tools were designed to retrieve information and conduct activities on the sea-bed. As early as the Bronze Age, artifacts intended to perform such tasks have been depicted (Figure 15) (Landstrom, 1970; Basch, 1987: 260–61, figs 563–5).

Sounding-weights for estimating water depth and sea bottom nature: Sounding weight/lead (SW) is a mass of bullet-shaped lead tied to a rope through which water depth can be estimated. Before the age of electronics, it was an essential navigation instrument for seamen and fishermen alike as it helped them to determine their position

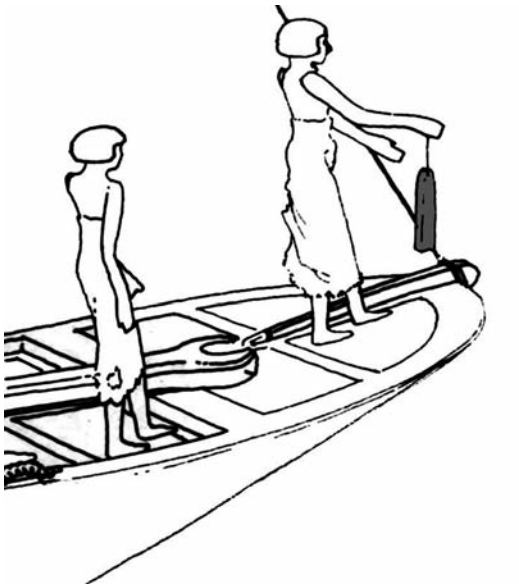

FIGURE 15

An Egyptian sailor casting a sounding-weight? (After the Cairo Museum).

when neither land nor sky marks were available (Oleson, 2000; Galili & Rosen, 2009). Additionally, SW could have brought a sea bottom sample that adhered to a sticky material (tallow) inserted in a tallow cup, thus helping to locate fishing grounds offshore. More than 94 SW have been thus far recovered in Israeli waters, all from the Mediterranean Sea (Oleson, 1988; Grossmann, 1994; Kingsley & Raveh, 1996; Oleson, 2000; Galili & Rosen, 2008b) (Figure 1). Their weights range from 0.96 to 20.6 kg, and most have a circular cross section though some are polygonal, with profiles differing among them.

Tying arrangements: The SW, like any non-disposable device cast overboard, is secured to a retrieval rope tied to perforated suspension lug, a perforation in its body or to a metal ring.

Tallow use and tallow holding methods: Most SW have tallow holding cups or grooves or a roughened surface on their base. Some have nails and holes on their sides or base.

Inscriptions and marks on the SW: About 20% of the SW collection carries inscriptions or marks. Marks were made by striking with a sharp instrument (a chisel?) after casting and they appear on the lug top, the shoulder, or the sides; often these marks are semi erased and obscure. There

FIGURE 16

Sounding weight decorated by crosses.

FIGURE 17
Inscriptions on sounding-weight (E. Galili).

are three groups of marks: crosses of four types (Figure 16); repeating geometrical patterns of fish bones, lozenges, and other depictions; and inscriptions (e.g., single letters, monograms, or words) (Figure 17). The letters and ligatures style on all the SW are from the 6th-7th centuries CE and none prior to the 6th century (Last Rosa, pers. com.).

Typology of Israeli Sounding Weights: Kapitän (1969-71) made the first attempt at creating a SW typology. Later, Oleson (2000) summarized previous studies and proposed a general classification system for ancient SW based on 177 SW from the Mediterranean and inland European waters (Oleson, 2008). Recently, a typology of Israeli SW has been established (Galili & Rosen, 2009). There are eight types here: Type 1: The most common in Israel (Figure 18). The suspension lug, usually square or rectangular, is cast with the body. Many have nail holes on the body side and are the only ones bearing decorations. Type 2 (The wide

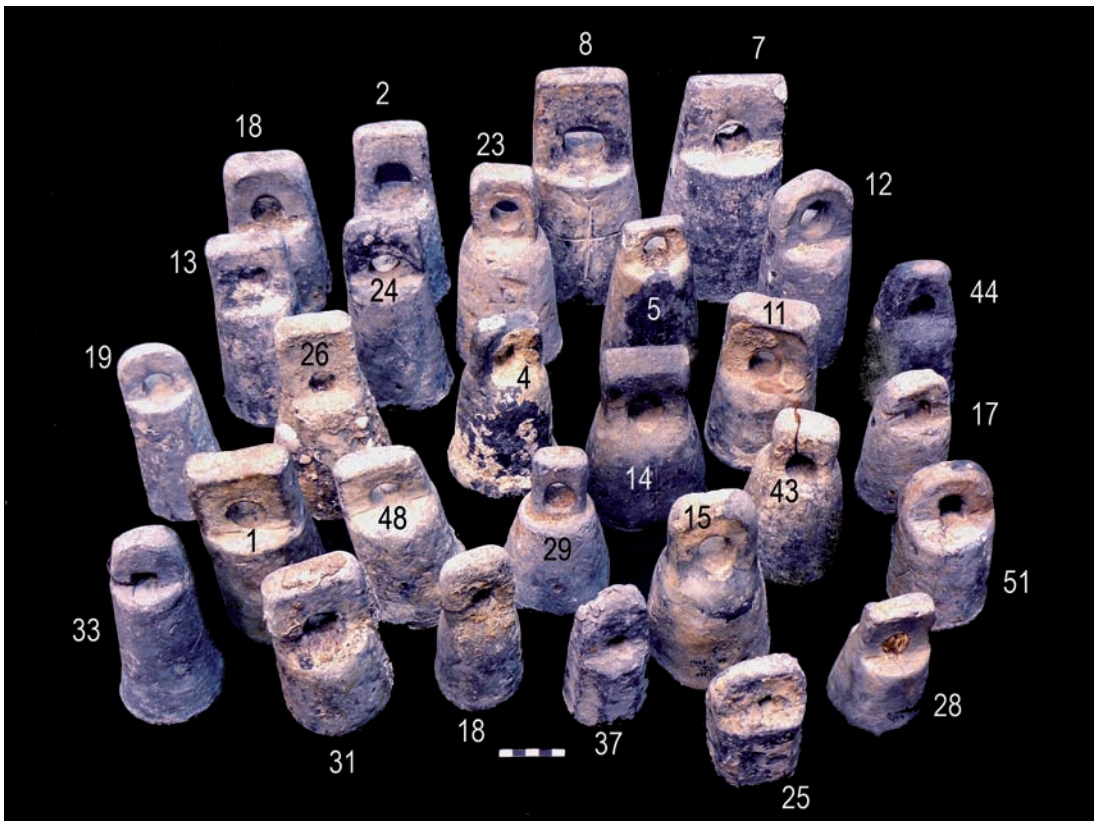

FIGURE 18
A collection of common sounding weights type 1 from Israel (E. Galili).

SW): A heterogeneous type with a very wide virtual head angle. Type 3 (SW with tying perforation in the body): It has a single round perforation in the body with no lug or metal ring. Type 4 (The intermediate SW): Their lugs were cast with the body. Many have nails penetrating the tallow cup. It is an intermediate type between 1 and 2. Type 5 (Miniature SW): Looking like functional SWs, these are significantly smaller (i.e., 4.5 to 8.5 cm). Such SW could have served some symbolic or ritualistic function. Type 6 (Bullet SW): These feature a bullet-like oval apex and have metal tying rings. Type 7 (Stone SW): These are made of stone and are similar to the leaden SW type 1. Type 8 (Long Bar SW): This type has an elongated body with hexagonal cross section, the tallow cup is shallow and plain and the sides are straight.

Provisional dating of Israeli SW types: The shape of the sounding weights is strongly dependent on their function and have changed little through time. Using datable archaeological assemblages and significant inscriptions recovered off the SW Israeli coast, a rough, period and cultural-related classification has been proposed: (a) Hellenistic-Roman: Types 4 and 6 may be associated with wreck sites from the Hellenistic and Roman periods (eg., Megadim south and Apollonia shipwreck sites) (Figure 1). (b) Late Roman- Byzantine: The earliest assemblage containing a well-defined specimen of type 1 SW is from Constantinus I time, at the beginning of the 4th century AD. A pair of two typical type 1 SWs, decorated with crosses, were recovered from the north Carmel coast in association with Byzantine coins. Another pair (one marked by crosses) associated with Byzantine coins, was recovered off Ashkelon Mayumas (Figure 1). It is suggested that this SW type was used from the 3rd to the 7th centuries AD. All imitations (both stone and miniature SW) of SW from Israel are imitations of type 1. (c) Medieval to Modern: The elongated SW (type 8) may be dated from medieval times to modernity (Oleson, 2000).

Grapnels for retrieving lost fishing gear: Two similarly elongated, round-sectioned, lead bars of unequal size were recovered off the Carmel coast (Figure 19). Both have a tying hole in one flattened end and purposefully-arranged holes containing the remains of vanished square iron «nails». The nails were inserted into the object point first, with the heads sticking out. These instruments are grapnels (Galili & Rosen, 2008b).

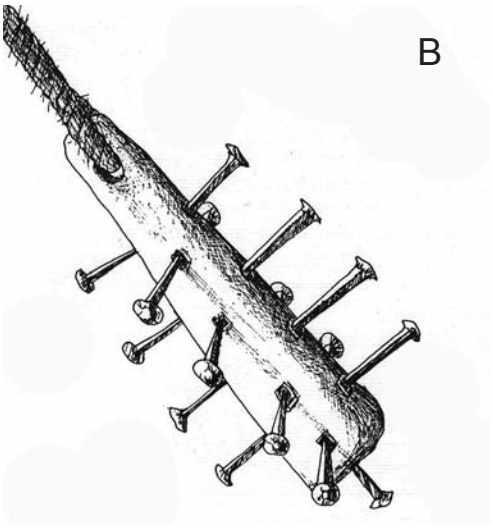

FIGURE 19

A) Grapnels from the Carmel coast Israel, and B) a reconstruction of grapnels used for salvaging lost nets (E. Galili, S. Ben Yehuda).

Similar grapnels made of natural tree branches are known from Neolithic and pre-modern Europe (Rau, 1884: 50). Grapnel anchors and other hook-

bearing tools are presently used by fishermen to locate and retrieve gear lost at sea. These two tools were probably made to perform a similar task.

Salvage rings (SR) for releasing entangled fishing gear: Fishing gear used at sea often gets entangled on the sea bottom at depths inaccessible for divers. Salvage rings (SR) made of various materials have long been used to release it. These are still used by traditional Israeli and Mediterranean fisherman (Laures, 1985; Pulak & Townsend, 1987; Oleson, 1994: 73; Galili & Rosen, 2008b) (Figure 20). Caught fish tend to flee to shelters, often dragging the gear along with them. Pulling the gear by force tears it and causes it to be lost. A salvage ring overcomes such problems. A boat is positioned over the entangled gear, and then the ring, secured by a salvage rope, is dropped down. The tightened fishing-line directs the ring exactly to where it is entangled. The ring works in two ways: It either releases the gear by pulling it downwards away from the rock overhang or crevice (Figure 21: A) or else repetitive dropping of the ring breaks the rock and releases the gear free (Figure 21: B). Altogether, 14 stone (Figure 22: A) and lead (Figure 22: B) SR have been recovered along the Israeli coast. A tentative typology of SR was suggested by Galili & Rosen (2008b). All have the basic ring shape but are of different external diameters and different weights (i.e. 0.7–25.4 kg). Their cross-sections are round, plano-convex, square or rectangular. Two of the stone SR are executed on limestone, two on local stones (i.e. marble or schist) and one on sandstone. A lead SR from Ashkelon bears an inscription perhaps marking ownership or a charm to ensure success. The letters and ligature styles of the inscription are from the 6th to 7th centuries A.D. (Rosa Last, pers. com.). Most SR were recovered from fishing grounds and are hard to date. A lead SR from Haifa is uniquely heavy (Galili & Sharvit,

FIGURE 20

Traditional iron salvage ring in use by fishermen in Akko (J. Galili).

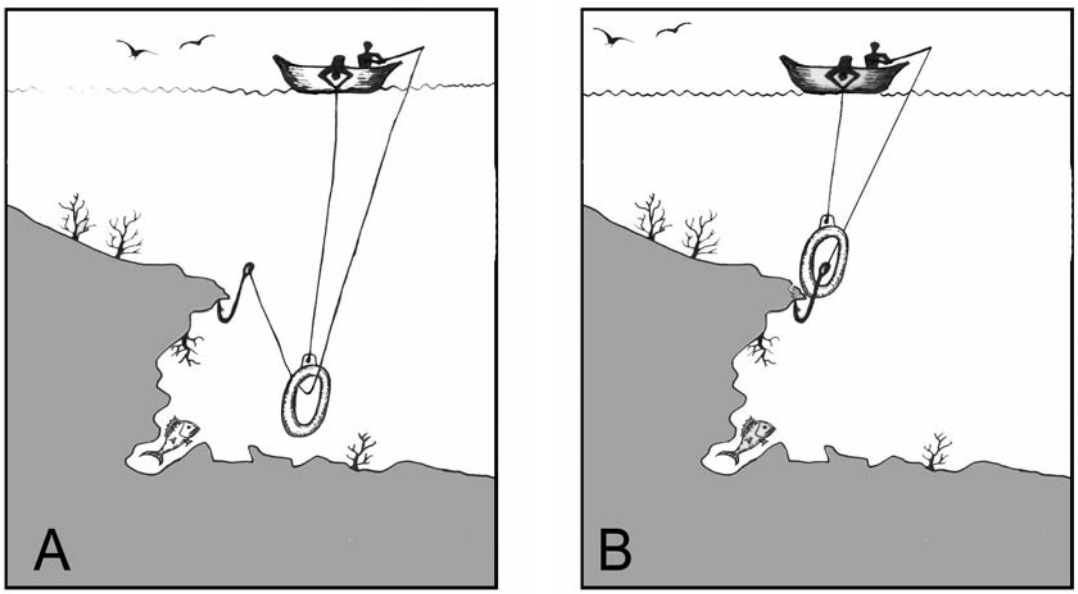

FIGURE 21

Different methods of operating salvage rings (E . Galili).

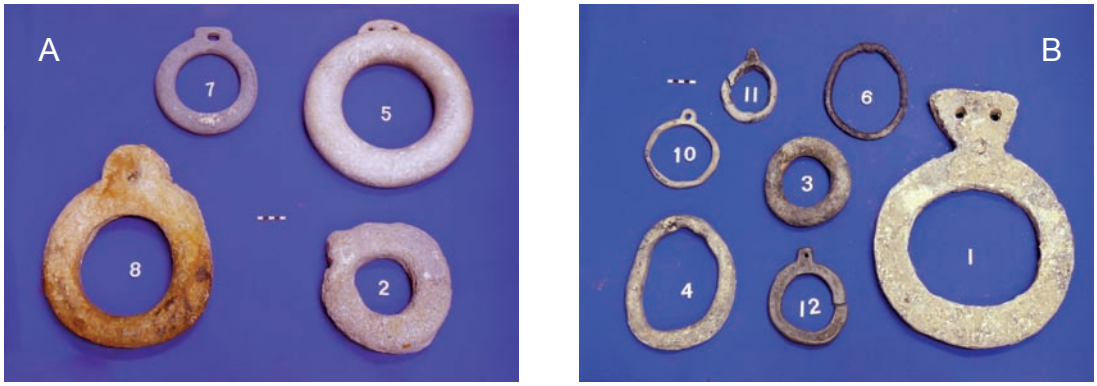

FIGURE 22

A) Stone salvage rings, and B) lead salvage rings from Israel (E. Galili).

1999), weighing more than five times the average weight thus far recorded (i.e., 25.4 kg *vs.* ca.5 kg). Possibly it served to salvage large fishing hooks, deep-sea long lines or nets entangled in deep water, or perhaps it was used by professional salvagers to free anchors. Such groups of commercial salvage divers are known from antiquity.

Coral-harvesting devices: Four five-holed square stones (Figure 23) were recovered off the Israeli coast (Figure 1). One of them, weighing 92 kg, was made of white, soft limestone snd was found off the Carmel coast (Frost, 2001). Two others, weighing 38 and 92 kg, were recovered from a 1st –century B.C. Hellenistic wreck off Megadim coast, north of Atlit (Galili & Rosen, 2008b). The last one was reported in 2010 by a fisherman diver off Ashkelon Tell (Yossi Ayalon, pers. com.). Similar five-holed stones have been found by divers in several north Mediterranean sites. It has been suggested that these were used as sinkers of coral-harvesting devices (Galasso, 1998; Frost, 2001; Galasso, 2001; Purpura, 2005). Red coral (*Corallium rubrum*) is a precious commodity often found in commercial quantities only in the western and central Mediterranean. Corals grow slowly and are easily over-exploited. Consequently, efforts were made to devise instruments that harvested coral at depths beyond the reach of free divers. One such instrument is a cross with nets or net bags hanging from the cross tips, and/or on ropes connecting the tips of the arms (Galasso, 1998: 18-31). Corals

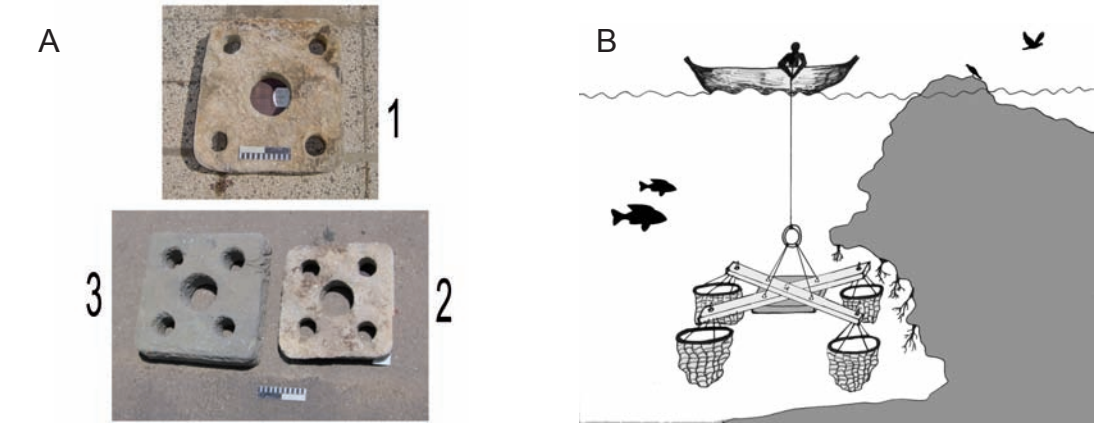

FIGURE 23

A) Five holed stones for coral harvesting from the Carmel coast, and B) a reconstruction of operating the instrument (E. Galili).

scraped off by the protruding arms are caught in the nets or fall into the bags and are lifted with the instrument. A heavy stone slab with four round holes in the corners to tie the cross arms and with a bigger round hole in the center to tie the whole instrument and facilitate lifting, was joined to the wooden cross (Figure 23B). Finds from Megadim (Galili & Rosen, 2008b) suggest that coral-harvesting devices were already in use in the Mediterranean by Hellenistic times. There are no red corals in Israeli waters today, nor have they been recovered in dredging or core drillings, suggesting that they were also absent in antiquity. The finds from the Israeli coast may thus indicate contact with coral-harvesting watercraft from the western Mediterranean.

Light-fishing with harpoon and cast net from the Dor 7th c. AD shipwreck: The ancient coastal site of Dor, occupied since at least 2000 BCE, is located on the central Carmel coast some 25 km south of Haifa (Figure 1). It is situated near one of the best protected natural shelters along the Israeli coast. Rescue surveys at Dor south anchorage revealed a pile of Kurkar ashlar stones and an assemblage of metal artifacts, including a fishing gear set (Galili & Rosen, 2008a). A total of 27 bronze coins and a «lump» containing an additional 53 dated the shipwreck to 659–663/4 AD. The artifacts used for fishing and fishing-related activities included a) Folded rectangular fishing gear sinkers made of lead; b) A striking head of a five-pronged iron spear with barbed prongs and a hollow, conical shaft housing (Figure 24); c) An iron fire basket for maintaining fire, probably a light-emitting device used to lure marine creatures. This device was formed of a shallow flat-bottomed

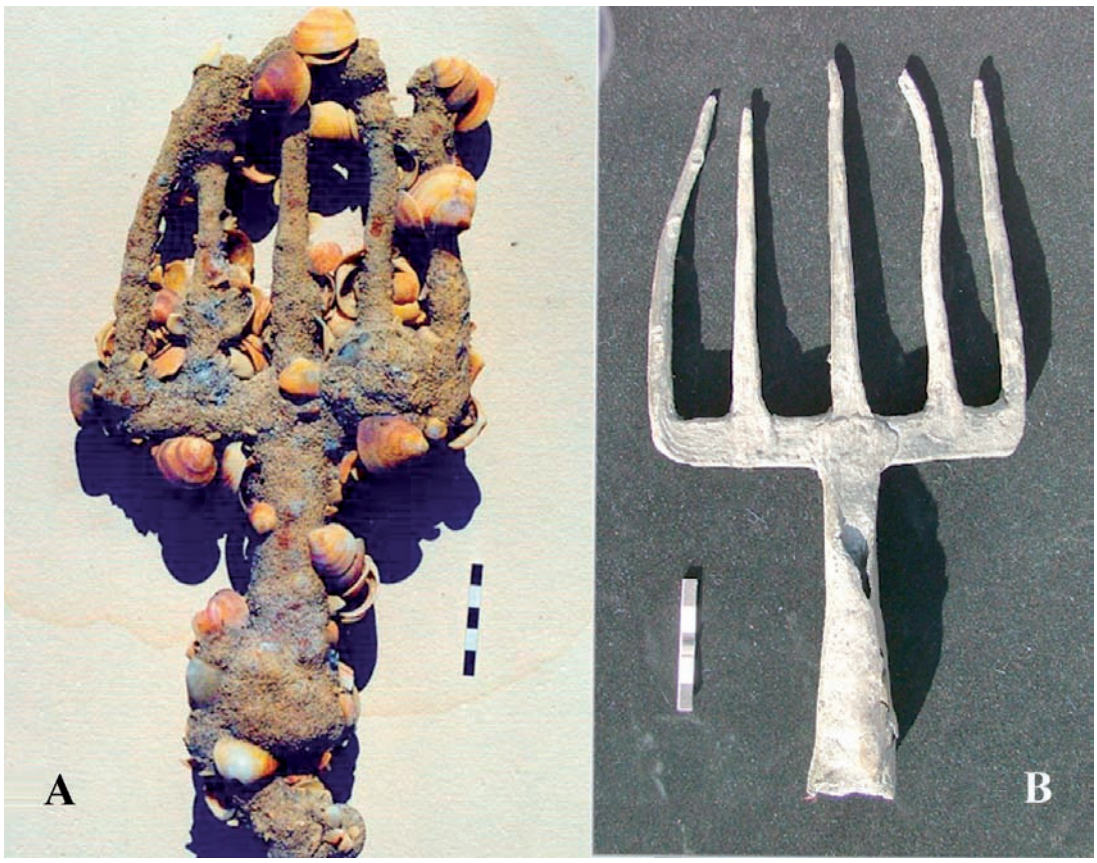

FIGURE 24

A Byzantine five pronged fishing spear head from Dor, before (A) and after (B) cleaning (E .Galili).

ellipsoid basket joined to a long handle housing, to protect the wooden handle (Figure 25); and d) a sounding weight weighing 6.410 g. whose hemispheric tallow cup contained traces of tallow (Rosen *et al*., 2001). The SW belongs to type 1 (Galili & Rosen, 2009), dated to the Late Roman - Byzantine shipwreck complexes of the 3rd-7th centuries C.E. (Galili & Rosen, 2008a). Judging from the latest of the minted coins, the wreckage occurred not much later than 665 C.E. (Syon & Galili, 2009), thus after the Muslim conquest. Iron nails found at the site indicate a medium size (i.e., 15-25 m) ship. Fishing by fire was practiced since prehistoric times. In the Mediterranean, such fishing generally involved the use of nets and tridents (Brandt, 1972: 106; Rosen, 1991). Absence of fishing hooks may testify that this assemblage represented a specialized professional kit of a fisherman fishing with a «lampara» (i.e., a torch using fire wood). Such fishing is practiced still today at night near the coasts to catch fish with nets and harpooning octopi. Sinkers recovered from the Dor wreck fit the characteristics of cast net sinkers. Modern traditional fishermen usually use seines to catch fish attracted by light. Use of cast nets in antiquity for this purpose is evidenced by an 11th C.E. manuscript (Figure 26). Archaeological evidence of light fishing devices is extremely rare throughout the world. The fishing kit discovered at Dor is thus a crucial archaeological item of evidence for light fishing in antiquity, and in fact, is the only material evidence in the ancient Eastern Mediterranean documenting such practice.

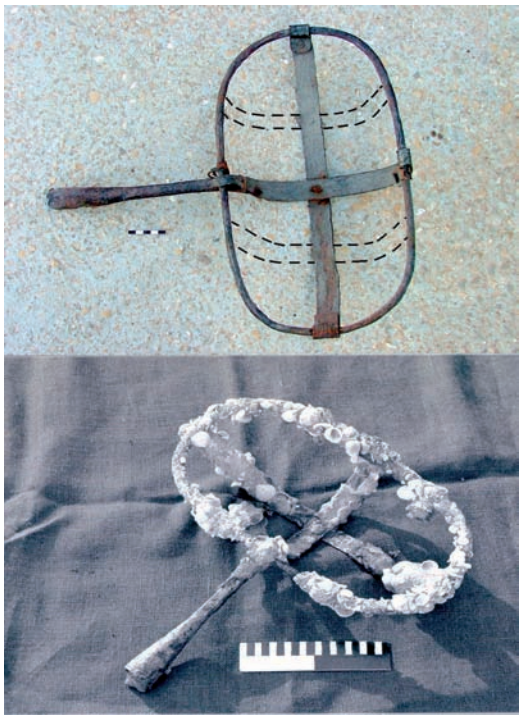

FIGURE 25

Iron fire basket from Dor, Byzantine period, before above and after cleaning (E. Galili).

FIGURE 26

A Late-Byzantine image of light-fishing using a cast net (After Galili & Rosen, 2008a).

DISCUSSION

Site formation of fishing gear from antiquity

The coast of Israel lacks natural shelters for ships. Over the millennia, ships that were sailing or anchoring there were hit by storms, drifted ashore, and wrecked. They were crushed in the breaker zone, and their remains scattered over the seabed at depths of 2-4 m. Most of the fishing gear described in this paper originated from shipwrecks. Fishing-gear found on a given underwater site may have been derived from fishing activity or from a shipwreck. This is so because wrecks, before complete disintegration, become fish habitats and thus attract fishermen. Fishing gear snagged during fishing activities may occasionally leave remains on the wreck (Frost, 1991: 355-410; Parker, 1992). Fishermen lose gear through storms and accidents and also while fishing. Fishing boats may be wrecked over fishing grounds or elsewhere and deposit remnants of their gear on the seabed. In addition to fishing vessels, watercraft of all sorts habitually carry fishing gear. Remnants of fishing gear were recovered from the harbor of Roman

Caesarea (Oleson, 1994), the port of Acre (Galili *et al*., 2010), and the anchorages of Yavneh-Yam (Raban & Galili, 1985; Galili & Sharvit, 1991: 111-121) and Dor (Kingsley & Raveh, 1996). The remnants of the fishing gear found in these ports and anchorages could have been lost through fishing in the harbor, or through wreckage events. When a vessel was wrecked, the fishing gear it carried sank, and, after the organic parts decayed, copper artifacts and lead sinkers survived (Frost, 1991: 355-410). They could have remained, sealed, and isolated, as within a «time capsule» (Kuniholm, 1982; Pulak, 1988) or else become mixed up with remains of intrusive gear. Fishing gear found on any underwater site may thus represent a combination of the site- formation processes just described.

LITERARY, ICONOGRAPHIC AND POETIC SOURCES OF MEDITERRANEAN FISHING TOOLS

Lists and inventories of fishing tools of any given society represent its relationships with the sea (Oswalt, 1976; Kuniholm, 1982; Brinkhuizen, 1983; Bekker-Nielsen, 2002). According to Plato's Sophist (355–347 B.C.E), hunting is divided into hunting and fishing. Two types of fishing, encircling and striking, are mentioned. Encircling is carried out with traps, nets, and similar implements. Striking is done with hooks and spears. Striking at night is classified as fire-hunting. Striking during the day is classified as barb hunting because striking tools, such as fishing hooks, are barbed. Barb hunting-fishing is further divided into two types, striking from below (hook), and striking from above (spear). Plato's scheme reflects a careful «Socratic», analytical listing of classical east Mediterranean fishing tools and demonstrates an understanding of fishing techniques, as befitting a scholar in a maritime society. The list also provides evidence of the importance of night fishing in the Greek Sea during Antiquity. According to Plato's scheme, the artifacts recovered along the Israeli coast may be listed as follows: 1) Encircling tools, represented here by the net sinkers; 2) Striking tools, represented by the fishing spears and hooks; and 3) Fire fishing tools, represented by the fire basket. After Plato several dedicatory epigrams in the Greek Anthology contain fishing tool lists (e.g., Patton, 1917: 1: 301). One example is an early epigram from the Hellenistic Period by Leonidas of Tarantum: *Diophantus the fishermen, as is fit, dedicated to the patron of his craft these relics of his old calling, his hook easily gulped down, his long poles, his line, his creels, this wheel, device of sea-faring nets-men for trapping fish, his sharp trident weapon of Poseidon, and two oars of his boats.* Another example from the Greek anthology is that of Philippus of Thessalonica, a late 1st century A.D. poet (Patton, 1917: 1: 301). According to it, Piso, the fisherman: «*His string-tipped rods and sea-swimming oar, the throat-biting barbs of his curved hooks, the lead-fringed nets, and the cork, spokesman for the weel, and his two rush-plaited creels, and the light-arousing fiery flint, pregnant with flame, and the anchor, that trap for drifting ships, - these Piso the fisherman brought to Hermes, his right hand already tremulous, overburdened with many labours*».

The nets listed in the epigrams were personal items and were probably cast nets with their lead sinkers («fringing the net»); in other words, the typical net of the individual fisherman. Also listed are traps with their floats, hooks with rods, and a fishing spear. The mention of flint for lighting fire demonstrates the importance of «fire fishing». As with archaeological finds, the epigrams list artifacts, such as oars and anchors, associated with the sea, though not exclusively used by fishermen. An additional literary source for ancient fishing tools is the *Halieutica* by Oppian (2nd century C.E.) a composition describing various methods of fishing. When Oppian lists fishing with hooks (Oppian trans., 1918: 351-353; Hal. 3.79 – 3.84), he divides this method into fishing with rod and without it. Fishing without rods is further subdivided into a line with single hooks and systems with many lines and hooks. This binomial system is similar to the one used by Plato. He listed several nets such as casting nets, draw nets, drag nets, round bag nets, cover nets, ground nets, ball nets, and crooked trawls. Also «fire fishing» is mentioned, and it clearly refers to «fire fishing» with trident, as was apparently the case in the Dor assemblage (Oppian trans., 1918: 451; Hal. 4.635).

ARCHAEOLOGICAL SOURCES OF FISHING TOOLS

Remnants of fishing gear were recovered from wrecks, harbors, fishing grounds, and land sites in

Israel and represent a biased sampling of past realities. Organic artifacts such as nets, floats and tools made of wood decompose fast, and the same happens to iron implements. Thus the study of fishing gear relies mainly on preserved items made from other metals and stones. Among the recovered artifacts, sinkers prevail, whereas hooks are common and fishing spears rare. Fishing tools were recovered from other underwater Mediterranean sites (Parker, 1992; Bernal Casasola, 2012), coastal and terrestrial alike. A Late Bronze age ship wreck assemblage containing lead net and line sinkers, netting tools, fishhooks, a harpoon and a bronze trident fishing spear were recovered from Ulu Burun shipwreck off South Turkey (Pulak, 1998). On land, a fishing kit, deposited as a votive gift, was discovered in the archaic temple at Isthmia, dated to the 6th century B.C.E (Raubitschek, 1998). It included a multi-pronged fishing spear (Isthmia VII, no. 457) and lead fishing net sinkers, (Isthmia VII, no. 456), probably the remains of a cast net according to the classification of Galili *et al*. (2002b). The much later Serce Limni shipwreck (11th century C.E.) carried three large nets with floats, a smaller casting net, a multi-tinged spear, netting tools, spindle whorls for making lines. Some of the fishing gear sinkers from this wreck had Christian symbols (van Doorninck, 1997). Fishing tools are depicted in Roman and Byzantine iconographic representations, generally mosaics, from numerous Mediterranean countries. Fishing tools identified on mosaics include hooks, with and without rods, multi-pronged spears, traps, cast nets, beach seines, and open-sea seines. The finds from the Israeli coast represent most of the fishing techniques described and depicted in the written and iconographic sources.

CONCLUSIONS

One conclusion of this study is the extreme diachronic and synchronic conservatism in the design and form of the fishing gear components. No real changes in the form of the long-lasting components have occurred since the Bronze Age till practically today. Little is known, however, about organic components of ancient fishing gear. Only few, very decayed, remnants of lines, nets, and fishing gear floats were retrieved by underwater archaeologists.

A shift to the use of iron alloys, often steel, for making fishing hooks instead of copper alloys occurred at some point though it remains unclear exactly when. The real revolution in fishing gear, and thus in the fish-fishermen equilibrium, occurred in the last 50-60 years with the appearance of non-rotting synthetic fibers which are familiar to any diver. Divers are aware of the devastating damage of lost modern nets, which uselessly kill marine life during prolonged time intervals. Probably, before the appearance of synthetic fibers, lost net underwater rotted and did not last for long. One of the important tasks for future underwater archaeologists will be to find the longevity of that human-made major global risk and to evaluate its impact on the marine environment.

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REFERENCES

Ariel, D.T. 2010: Coin hoard from a fourth-Century CE shipwreck off the Carmel coast. *'Atiqot* (English Series) 63: 61-110.

Avitsur, S. 1976: *Man and his work*. Carta, Jerusalem. [In Hebrew].

Baranov, F.I. 1970: Theory and practice of commercial fishing, vol. 2 of *Selected works on fishing gear*. (E. Vilim, translation). Israel Program for Scientific Translations, Jerusalem.

Basch, L. 1987: *Le musée imaginaire de la marine antique*. Institute hellénique pour la préservation de la tradition nautique, Athens.

Bekker-Nielsen, T. 2002: Nets, boats and fishing in the Roman World. *Classica et Medievalia* 53: 215-233.

Bernal Casasola, D. 2012: Catálogo de la Exposición Pescar con Artes Fenicios y Romanos en el origen de

los aparejos andaluces. Servicio de Publicaciones. Universidad de Cádiz. Cádiz.

BRANDT, A. Von 1972: *Fish catching methods of the world*. Fishing News (Books), London.

BREWER, D.J. & FRIEDMANN, R.F. 1989: Fish and Fishing in Ancient Egypt. Aries & Phillip, Warminster.

BRINKHUIZEN, D. 1983: Some notes on recent and protohistoric fishing gear from Northwestern Europe. *Palaeohistoria* 25: 7-54.

COLONESE, A.C.; MANNINO, M.A.; BAR-YOSEF MAYER, D.E.; FA, D.A.; FINLAYSON, C.; LUBELL, D. & STINER, M.C. 2010: Marine mollusc exploitation in Mediterranean prehistory: an overview. *Quaternary International* 239: 86-103.

CORTÉS-SANCHEZ, M.; MORALES-MUñIZ, A.; SIMÓN-VALLEJO, M.D.; LOZANO-FRANCISCO, M.C.; VERA-PELAEZ, J.L.; FINLAYSON, C.; RODRíGUEZ-VIDAL, J.; DELGADO-HUERTAS, A.; JIMÉNEZ-ESPEJO, F.J.; MARTíNEZ-RUIZ, F.; MARTíNEZ-AGUIRRE, M.A.; PASCUAL-GRANGED, A.J.; BERGADA-ZAPATA, M.M.; GIBAJA-BAO, F.; RIQUELME-CANTAL, J.A.; LÓPEZ-SAEZ, J.A.; RODRIGO-GAMIZ, J.; SAKAI, S.; SUGISAKI, S.; FINLAYSON, G.; FA, G. & FERREIRA BICHO, N. 2011: Earliest Known Use of Marine Ressources by Neanderthals. *PlosONE* 6(9): e24026.

ELGAVISH, J. 1994: *Shiqmona on the seacoast of Mount Carmel*. Hakibbutz Hameuchad Publishing House and the Israel Exploration Society, Tel-Aviv. [In Hebrew].

FROST, H. 1991: Anchors sacred and profane, Ugarit-Ras Shamra, 1986; the stone anchors revised and compared. In: Yon, M. (ed.): *Ras Shamra-Ougarit VI: Arts et industries de la pierre*: 355-410. Editions Recherche sur les Civilisations, Paris.

FROST, H. 2001: Anchor look-alikes. *Tropis* 6: 197-206.

GALASSO, M. 1998: Unterwasserfunde in West-Sardinien. *Zeischrift fur Unterwasserarcaologie* 1: 18-31.

GALASSO, M. 2001: *La pesca del corallo in Sardegna: evoluzione, persistenze e innovazioni tecniche*. Centro Studi sul Corallo (*Coralium rubrum* L.). Sassari.

GALILI, E. & NIR, Y. 1993: The submerged Pre-Pottery Neolithic water well of Atlit-Yam, northern Israel, and its palaeoenvironmental implications. *The Holocene* 3: 265-270.

GALILI, E. & ROSEN, B. 2008a: Fishing gear from a 7th century shipwreck off Dor, Israel. *The International Journal of Nautical Archaeology* 37(1): 67-76.

GALILI, E. & ROSEN, B. 2008b: Ancient remotely operating instruments recovered underwater off the Israeli coast. *The International Journal of Nautical Archaeology* 37(2): 283-294.

GALILI, E. & ROSEN, B. 2009: Ancient sounding weights and navigation along the Mediterranean coast of Israel. *The International Journal of Nautical Archaeology* 38(2): 343-368.

GALILI, E. & SHARVIT, J. 1991: Yavneh-Yam anchorage, finds from the underwater survey. In: Fisher, M. (ed.): *Yavneh-Yam and its Surroundings*: 303-314. Ariel, Jerusalem. [In Hebrew].

GALILI, E. & SHARVIT, J. 1999: Haifa, underwater surveys. Hadashot Arkheologiyot. *Excavations and Surveys in Israel* 110: 15-20. (Hebrew; English).

GALILI, E.; LERNAU, O. & ZOHAR, I. 2004: Fishing and coastal adaptations at Atlit-Yam, a submerged Neolithic village off the Carmel coast, Israel. *'Atiqot* 48: 1-34.

GALILI, E.; ROSEN, B. & SHARVIT, J. 2002b: Fishing gear sinkers recovered from an underwater wreckage site, off the Carmel coast, Israel. *The International Journal of Nautical Archaeology* 31(2): 182-201.

GALILI, E.; ROSEN, B. & SHARVIT, J. 2010: Artifact assemblage recovered from a Roman shipwreck Off the Carmel coast, Israel. *'Atiqot* 63: 61-110.

GALILI, E.; ESHED, V.; GOPHER, A. & HERSHKOVITZ, I. 2005: Burial practices at the submerged PPNC site of Atlit-Yam, northern coast of Israel. *Bulletin of the American Schools of Oriental Research* 339: 1-19.

GALILI, E.; ROSEN, B.; GOPHER, A. & KOLSKA-HORWITZ, L. 2002a: The emergence and dispersion of the eastern Mediterranean fishing village: evidence from submerged Neolithic settlements off the Carmel coast, Israel. *Journal of Mediterranean Archaeology* 15(2): 167-198.

GALILI, E.; ROSEN, B.; ZVIELY, D.; SILBERSTEIN, N. & FINKIELSZTEJN, G. 2010: The evolution of Akko harbor and its Mediterranean maritime trade links. *Journal of Island and coastal Archaeology* 5(2): 191-211.

GALILI, E.; WEINSTEIN-EVRON, M.; HERSHKOVITZ, I.; GOPHER, A.; KISLEV, M.; LERNAU, O.; KOLSKA-HOROWITZ, L. & LERNAU, H. 1993: Atlit-Yam: a prehistoric site on the sea floor off the Israeli coast. *Journal of Field Archaeology* 20(2): 133-156.

GROPHIT, E. 1991: *Fishing in Israel in 1991*. Ministry of Agriculture, Tel-Aviv. [In Hebrew].

GROSSMANN, E. 1994: Sounding-leads from Apollonia, Israel. *The International Journal of Nautical Archaeology* 23(3): 247-249.

HARTMANN, A. 1997: *Landscape and agriculture of the Carmel coastal plain in the PPNC period, reconstruction from plant macrofossils of Atlit-Yam well*. MA Thesis, Bar-Ilan University, Department of Land-of-Israel Studies. [Hebrew].

HERSHKOVITZ, I. & GALILI, E. 1990: 8000 Year-old human remains on the sea floor near Atlit, Israel. *Journal of Human Evolution* 5: 319-358.

HIGGINBOTHAM, J. 1997: *Piscinae, artificial fishponds in Roman Italy*. The University of North California Press, Chapel Hill.

HORNELL, J. 1935: *Report on the fisheries of Palestine*. Crown Agents for the Colonies, London.

KAPITã N, G. 1969-1971: Ancient anchors and lead plummets. *Sefunim* 3: 51-61.

KINGSLEY, S.A. & RAVEH, K. 1996: *The ancient harbour and anchorage at Dor, Israel: results of the underwater surveys, 1976-1991*. B.A.R. (International Series) 626. Tempus Reparatum, Oxford.

KNIGHT, A.M. 1918: *Modern seamanship*. D. Van Nostrand Company, New-York.

KUNIHOLM, P.I. 1982: The fishing gear. In: Bass, G.F. & van Doorninck, F.H. Jr. (eds.): *Yassi Ada I: a seventh-century Byzantine shipwreck*: 296-310. Texas A & M University Press, College Station.

LANDSTROM, B. 1970: *Ships of the Pharaohs*. Allen & Unwin, London.

LAURES, F.F. 1985: The line or net «Free-er» ring. *The International Journal of Nautical Archaeology* 14: 80-82.

MARAZANO, A. & BRIZZI, G. 2009: Costly display or economic investment? A quantitative approach to the study of marine aquaculture. *Journal of Roman Archaeology* 22: 215-230.

MESHORER, Y. 2010: Coin hoard from a Third-Century CE shipwreck off the Carmel coast. '*Atiqot* 63: 61-110.

NADEL, D.; DANIN, A.; WERKER, E.; SCHICK, T.; KISLEV, M.E. & STEWART, K. 1994: 19,000-year-old twisted fibers from Ohalo II. *Current Anthropology*, 35:451-458.

NUN, M. 1964: *Ancient Jewish fishery*. Hakibutz Hameuchad Publishing House, Merhavya. [In Hebrew].

NUN, M. 1993: *Ancient stone anchors and net sinkers from the Sea of Galilee*. Kibbutz Ein Gev. [In Hebrew].

OLESON, J.P. 1988: Ancient lead circles and sounding-leads from Israel coastal waters. *Sefunim* 7: 27-40.

OLESON, J.P. 1994: Non-ceramic finds: general discussion of types and catalogues of unstratified examples. In: Oleson, J.P. (ed.): *The harbours of Caesarea Maritima, results of the Caesarea ancient harbour excavation project, 1980-85, Vol. II: the finds and the ship*: 65-76. B.A.R. (International Series) 594. Tempus Reparatum, Oxford.

OLESON, J.P. 2000: Ancient sounding-weights: a contribution to the history of Mediterranean navigation. *Journal of Roman Archaeology* 13: 293-310.

OLESON, J.P. 2008: Testing the waters: the role of sounding weights in ancient Mediterranean navigation. In: Holfelder, R.L. (ed.): *The maritime world of ancient Rome*: 119-176. University of Michigan Press, Ann Arbor.

OPPIAN: *Halieutica*. A.W. Mair transl. (Loeb Classical Library) Mass. 1928 (repr. 1963), London.

OSWALT, W.H. 1976: *An anthropological analysis of food-getting technology*. Wiley, New-York.

PARKER, A.J. 1992: *Ancient shipwrecks of the Mediterranean and the Roman provinces*. B.A.R. (International Series) 580. Tempus Reparatum, Oxford.

PATTON, W.R. 1917: *The Greek anthology*. (Loeb Classical Library), Mass. transl.1918, rep. 1960, London.

PETRIE, W.M.F. 1933: *Ancient Gaza III, Tel El Ajjul*. British School of Archaeology in Egypt, London.

PETRIE, W.M.F. 1974 (1917): *Tools and weapons*. Aris & Phillips, Warminster England.

POWELL, J. 1996: *Fishing in the prehistoric Aegean*. Vol. 137 of Studies in Mediterranean archaeology and literature. Astrom, Jonsered.

PRITCHARD, J.B. 1978: *Recovering Sarepta, a Phoenician city: excavations at Sarepta, Lebanon, 1969-1974, by the University Museum of the University of Pennsylvania*. Princeton University Press, Princeton.

PULAK, C.M. 1988: The Bronze Age shipwreck at Ulu Burun, Turkey, 1985 Campaign. *American Journal of Archaeology* 92(1): 11-37.

PULAK, C.M. 1998: The Uluburun shipwreck: an overview. *The International Journal of Nautical Archaeology* 27(3): 188-224.

PULAK, C.M. & TOWENSEND, R.F. 1987: The Hellenistic shipwreck at Serce Limani, Turkey: preliminary report. *American Journal of Archaeology* 91(1): 31-44.

PURPURA, G. 2005: Osservazioni sulla pesca del corallo rosso nell'antichità. *Archaeologia Maritima Mediterranea* 2: 93-106.

RABAN, A. & GALILI, E. 1985: Recent maritime archaeological research in Israel: a preliminary report. *The International Journal of Nautical Archaeology* 14(4): 321-356.

RAU, C. 1884: *Prehistoric fishing in Europe and north America*. Smithsonian Contribution to Knowledge 509. Smithsonian Institution, Washington D.C.

RAUBITSCHEK, I.K. 1998: *The metal objects (1952-1989), vol. VII of Isthmia: excavations by the University of Chicago under the auspices of the American School of Classical Studies at Athens*. American School of Classical Studies at Athens, Princeton.

ROSEN, B. 1991: An apostate Jewess from Tyre: The abbess of a Monophysite monastery south of Caesarea. *Cathedra* 61: 54-66. [In Hebrew].

ROSEN, B.; GALILI, E. & SHARVIT, J. 2001: Traces of fatty acids from a Byzantine sounding lead recovered off

the Israeli coast. *Journal of Archaeological Science* 28: 1323-1327.

ROSSANAGEL, W.E. 1950: *Handbook of Rigging*. McGrowhill, New-York.

STEWART, H. 1981: *Artifacts of the northwest coast Indians*. Hancock House Publishing, Vancouver.

STEWART, H. 1982: Indian fishing: early methods on the northwest coast. Douglas & McIntyre, Vancouver.

SUNDSTROM, G.T. 1957: Commercial fishing vessels and gear. Bureau of Commercial Fisheries, Circular 48. Washington D.C.

SYON, D. & GALILI, E. 2009: Byzantine-period bronze coins from the sea at Dor. *'Atiqot* 61: 81-94.

VAN DOORNINCK, F.H. Jr. 1997: Glasvraget-et byzantinsk skib fra 1000-tallet. *Hvad Middelhavet gemmer* 1: 121-136.

VAN NEER, W.; ZOHAR, I. & LERNAU, O. 2005: The Emergence of Fishing Communities in the Eastern Mediterranean Region: A survey of evidence from Pre-and Protohistoric periods. *Paléorient*, 31:131-157.

WRESCHNER, E.E. 1983: The submerged Neolithic village «Neve-Yam» on the Israeli Mediterranean coast. In: Masters, P.M. & Flemming, N.C. (eds.): *Quaternary coastlines and marine archaeology: towards the prehistory of land bridges and continental shelves*: 325-344. Academic Press, London.

ZEMER, A. 1999: *Castra at the foot of Mount Carmel: the town and its hidden secrets*. Exhibition catalogue. The National Maritime Museum, Haifa.

ZOHAR, I.; DAYAN, T.; SPANIER, E.; GALILI, E. & LERNAU, O. 1994: Exploitation of the grey triggerfish (*Balistes carolinensis*) by the prehistoric inhabitants of Atlit-Yam, Israel: a preliminary report. In: van Neer, W. (ed.): Proceedings of the 7th meeting of the ICAZ Fish Remains Working Group. *Annales du Musee Royal de l'Afrique Centrale* (Sciences Zoologiques) 274: 231-237.

ZOHAR, I.; DAYAN, T.; GALILI, E. & SPANIER, E. 2001: Fish processing during the Early Holocene: a taphonomic case study from coasts, Israel. *Journal of Archaeological Science* 28: 1041-1053.