Chapter 1

The Akko Marina Archaeological Project – Introduction

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Introduction

Akko (Acre) is a Mediterranean harbor city that has been functioning for thousands of years (Fig. 1).
It is a unique site and was recently recognized by UNESCO as a World Heritage Site. Akko has been the scene of diverse human activities over the millennia. The bay just south of the city has served as a natural anchorage and harbor. The unique geo-hydrographic characteristics of Akko's southern shoreline, protected from western and northern winds by the Akko headland, gave the place natural advantages as a safe haven for anchoring sailing vessels and as a base for the construction of a harbor. The Akko Harbor is one of the three ancient built harbors on the coast of Israel. This harbor served as a gateway for thousands of years, with vessels arriving regularly from all across the Mediterranean. The harbor served foreign armies, pilgrims, local and international commerce, and is mentioned in numerous ancient sources. The importance of the Akko Harbor is attested by continuous descriptions, with documentation of the harbor and its means of access, beginning on coins of the Roman period, and, from the thirteenth century, drawings, sketches, portolans, charts and written descriptions (Galili *et al.* this volume a). No similar abundance of navigational aids can be found for other ancient anchorages or harbors along Israel's coast, such as Atlit (Athlit), Caesarea, Jaffa or Ashkelon (Ascalon), which also hosted maritime activity beginning in antiquity. Numerous archaeological studies of the city of Akko and its harbor have been undertaken over recent decades. Nevertheless, several archaeological and historical issues remain unresolved. For example, the date of construction and end of use of the harbor's facilities; its boundaries in various periods; its array of piers and arrangements for mooring and anchoring vessels of various sizes; the location of the harbor's entrance; problems of siltation of the harbor in various periods and the harbor's destruction by human and natural agents. The harbor exerted a major influence on the social and economic life of the city and the answers to these issues can greatly assist in the understanding of its history.
Geological, geomorphological and sedimentological processes naturally change the coast, causing erosion and destruction on the one hand, and accretion on the other. These processes – and human intervention in the coastal environment in the form of development and construction of maritime structures, quarrying of sand, reclaiming land from the sea and the quarrying of *kurkar* – quickly destroy nearby ancient harbor structures and installations. Marine archaeological remnants in and around the harbor and iconographic descriptions are key testimony that can help us understand the history of the harbor and the human activity it encompassed. Historic Akko, which exists to this day, is situated atop ancient remains. Extensive development and infrastructure work have been undertaken to maintain a level of modern services that meet the needs of a population in the late twentieth and early twenty-first centuries, and to improve the city's appearance and make it attractive to local and foreign tourists. Infrastructure work for road construction, sewage, water supply, electricity, communications, and the preparation of structures for tourist services, commerce, residential housing and hotel accommodations, makes it necessary to deal daily with the ancient cultural remains found everywhere in the city. Construction and development, which involved work in the sea itself, required preliminary archaeological surveys, underwater excavations and ongoing supervision. Such work was needed to uncover ancient remains, study them and assess their importance, document and map them and identify the sites and finds that should be preserved *in situ* for the generations to come.
This report presents findings from an underwater survey conducted by the IAA (Israel Antiquities Authority) during deepening of the Akko Marina from 1992 to 1993 and finds from subsequent surveys at the sites where material dredged from the marina was deposited in the open sea. In addition, remains of recovered water crafts are briefly described, along with cargo and findings during underwater and coastal surveys conducted by the IAA in and around the Akko Marina from 1988 to 2004.

Fig. 1: Location map and aerial photograph of the Akko Peninsula, view from the southeast (aerial photo: A. Ohayon)

Finds uncovered until 2014 during archaeological activities by other entities in the Akko Marina are also discussed. Some of the findings can be attributed to discrete assemblages from shipwrecks or harbor installations; others were scattered without clear archaeological context.

The Physical Conditions of the Akko Harbor and its Surroundings

The Akko Harbor is located at the northern end of the Haifa Bay, which is the largest coastal embayment in Israel and the continuation of the valleys of Zevulun and Akko. The bay is bounded on the north by the Ahihud Fault, through which the Na'aman River flows. On the south it is bounded by the northern edges of the Carmel range, through which the Kishon River flows (Galili and Rosen this volume e: figs. 1, 4). The Haifa Bay faces the open sea to the west, and during winter storms cannot provide proper safe haven for ships. The Haifa Bay is a sedimentary sink and the edge of the Nile littoral cell. The shoreline of the bay is sandy except for the southern shore of the Akko headland and Haifa's Bat Galim Beach. During winter storms the Akko Harbor is exposed to the waves and currents from the southwest; anchoring there is dangerous in winter. During spring summer, and fall,

however, the Akko Harbor provides good protection from northern winds. Southwestern summer storms are not particularly powerful and it may be assumed that the Akko Harbor could be used during the summer. The bottom of the Akko Bay is covered with pebbles, coarse carbonatic sand, and clays carried by the flooding of the Na'aman River and fine quartz sand brought by the sea currents.West of the foundation of the ancient breakwater,the seabed is rocky and the Crusader walls are built on *kurkar* abrasion platforms – remains of the *kurkar* ridge that was mostly quarried for building stone. The basin of the modern fishing harbor is in same place as the ancient harbor once was, and the line of the modern southern breakwater was built mainly over the ancient breakwater (Figs. 1, 2). Because the basin is closed, there was low energy in it. This resulted in the deposition of clays and fine sediments over thousands of years. In these clayey deposits, which are several meters thick, are remains of ships, cargos, and numerous archaeological objects originating from ships that were wrecked in the harbor or were abandoned. These layers also contain refuse that was discarded or inadvertently fell overboard. East of the marina is a large sandy area (the easern basin) measuring 300 × 300 m, bounded on the east by a rampart that connected the Island of Flies with the shore. According to several scholars, these are the remains of the eastern breakwater from the Early Muslim period, (see summary Galili and Rosen this volume e). This area, which may have served as part of the Crusader and Mamluk harbor basin, was blocked by sand as much as several meters thick. East of the rampart is a sandy area with a beach facing southwest and extending toward the eastern beaches of the Haifa Bay (Galili and Rosen this volume e: figs. 1, 4, 9).

Historical Background

The coast of Israel, which is ca. 196 km long, is mostly straight, with few natural safe havens for ships. Over some 5,000 years, this coastline served as an active shipping lane, constituting a bridge between civilizations. This coast witnessed intensive shipping, trade, fishing, wars, pilgrimage and other seaborne activities. The Haifa Bay, the largest in Israel, is exposed to the wind and therefore could not serve as a safe haven for sailing vessels during storms. The Akko Bay, located in the northern part of the Haifa Bay, could provide relatively good shelter, particularly during northern storms. Thus the sea opposite Akko, between the Na'aman estuary and the southern part of the city, served as a major center of maritime activities for thousands of years.

The archaeological findings in the excavations of Tel Akko (Tell el-Fukhar) revealed extensive trade relations beginning in the early second millennium BCE (Middle Bronze Age IIA). At that time, the existence of the city was already tied to maritime commerce, and so it may be assumed that the city had a harbor or anchorage. Research cannot clearly indicate the presence or location of such early harbor; however, it was suggested that the Na'aman River and its estuary served as an inland safe haven for ships (Raban 1993).

Beginning in the Persian period, in the sixth–fifth centuries BCE, the city began to spread beyond the mound, and Phoenician Akko was the staging area for the Persian forces on their way to Egypt. According to Raban (1993: 29–31), the great Persian fleet and the logistical forces supporting it, could not make do with the shelter provided by the Na'aman. It was assumed that the harbor was first built in its current location in the sixth century BCE for the benefit of the fleet of the Persian King Cambyses. According to Raban (1983: 146), the Phoenicians built another, open anchorage near the existing harbor, now known as the Island of Flies.

At the end of the fourth century BCE the city became a Greek polis. Its location and its convenient harbor significantly increased its importance, and it took the name Ptolemais, after King Ptolemy (the Ptolemaic dynasty ruled Egypt during the Hellenistic period, 305 BCE to 30 BCE). It fairly quickly became one of the most important cities in the region. At its height, its jurisdiction extended southward beyond Mount Carmel and northward to the mountain ridge known as the Ladder of Tyre. Historical and archaeological evidence from the Hellenistic period reveal the importance and prosperity of the city. Greek inscriptions, an abundance of wine jars imported from Greece, consumed by non-Jews and soldiers, and the bones of elephants belonging to the Hellenistic army, were discovered in excavations. The recently uncovered Hellenistic-era residential quarter, with its wealth of colored plaster fragments, attests to a high standard of living. As an important and wealthy capital city, it was surrounded by fortifications. A city wall built of ashlars, 3 m thick, has been discovered near the present-day Tambour factory. On the slopes of the Western Galilee Mountains five fortresses have been discovered, which apparently protected Akko's land flank. Near Moshav Regba an aqueduct was discovered, hewn in the *kurkar* ridge, which led water from the Kabri Springs. Only a major city with ample resources could have funded the construction of such an aqueduct in the Hellenistic period. Beginning at that time, the city began to mint its own coins, a right reserved only for important cities. Because of its importance, Alexander Jannaeus (Hasmonean king, died 76 BCE) imposed a lengthy siege on the city, but was unable to conquer it.

During the Roman period, until the construction of the harbor of Caesarea (building started in 10 BCE), the Akko Harbor was the most important gateway to Europe and to Rome and its European territories. Akko's strategic location and the importance of its harbor led to its renovation, including the raising and

extension of the southern breakwater. Roman Akko continued to be a key non-Jewish urban center, which existed alongside Jewish Galilee. The importance of the city can be gleaned from the works of Josephus Flavius (a Jewish military leader who was captured by the Romans and later became a historian; died in 100 CE). In 39 BCE, Herod (A Jewish Roman client king of Judea, 74–4 BCE) disembarked at Akko when he returned from Rome after being crowned by the Roman Senate (*Ant.* 376; *Wars* 290). After his return from Rome, it was in Akko that Herod raised an army of mercenaries of various ethnic origins to fight Antigonus (the last Hasmonean king of Judea, died 37 BCE; *Ant.* 394; *Wars* 290). In 30 BCE, Herod met Octavian (Augustus) in Akko and welcomed him grandly to a luxurious palace, when Octavian was on his way to Egypt to fight Anthony and Cleopatra after the battle of Actium (*Ant.* 385). Herod knew the strategic value of Akko as the gateway to Rome and to the entire Mediterranean, and it may be assumed that the fact that this important harbor city was outside his realm influenced his decision to build the harbor of Caesarea.

It was at the Akko Harbor that the Roman legions landed to quell the Jewish Great Revolt in Galilee (66–67 CE); the banners of these four legions appear on a bronze coin minted in the city during the time of Emperor Nero. On a city coin the harbor is depicted as a semicircle surrounded by towers with ships entering it. That unique depiction of a harbor on a city coin is a clear evidence of Akko's importance. Another coin shows a mound east of Akko, topped by a fortress to which a winding road ascends. At the bottom of the coin a ship is shown with another detail that appears to be a lighthouse (Galili *et al.* this volume a). Beginning in the reign of Nero (54–68 CE) the title Colonia was bestowed on the city, and after the Great Revolt, the Jewish population returned there and once again became involved in the city's commercial and economic life. There were many public buildings in the city from the Roman period, among them a temple to Jupiter and the Capitoline Triad.

During the Byzantine period, Akko was a regional capital with its own bishop, as well as a shipbuilding yard. Although not a single church from this period has yet been discovered, written sources reveal the names of a number of bishops who served there. With the Arab conquest (644 CE), the city went back to its original name, Akka-Akko, after about 1,000 years during which the foreign name Ptolemais was used.

During the Early Muslim period, at the time of the Umayyad Caliph Mu'awiya (reign, 661–680 CE), the Akko Harbor was very active. The shipyard that had operated during the Byzantine period was reopened and the harbor became the second largest Arab navy base in the Eastern Mediterranean after Alexandria. During the 880s CE, Ahmed Ibn Tulun, the Abbasid governor of Palestine and Egypt, expanded and enlarged the harbor in a manner resembling the harbor of Tyre to the north. The Jerusalem historian Al-Muqaddasi described the work, which was planned and implemented by his own grandfather, the Jerusalem architect Abu Bakr.

The Crusaders made Akko and its harbor their main naval base linking them to Europe. Between 1191–1291 CE, Akko was the capital of the realm and the nexus of Christian military and the center of economic and commercial activities. The city was the headquarters of the Crusader military orders and of the administration established by the Italian maritime powers in the Levant. Activity in Akko and its harbor during the Crusader era left behind an abundance of maps, documents and archaeological remains. According to historical descriptions, the city's harbor during Crusader times was identical to the one from the era of Ibn Tulun, its main drawback being its small size (ca. 60,000sq m), which was insufficient, especially in the spring and summer. Due to siltation of the harbor large ships had to anchor outside the protected area near the Na'aman estuary, and south of the southern breakwater.

During the Mamluk and the early Ottoman periods (from the destruction of the city at the end of the Crusader period in 1291 CE and until the early seventeenth century), the harbor lay in ruins. However, there is evidence that it was used at this time by Venetian merchants for the export of cotton and the transport of pilgrims (Ashtor 1983: 379; Shor 1990: 161–163; Galili and Rosen this volume a) and for trade with Venice. Fakhr al-Din II (1572–1635, leader of the Emirate of Shouf) restored the harbor and renewed international trade, but in 1613, shortly after the renovation, he ordered the harbor to be demolished to prevent Turkish access to the city. During the 1740s the city was taken over by Dahar al-Omar (virtually autonomous ruler of northern Palestine, lived 1688–1775), who encouraged merchants, especially the French, to visit the city. According to eighteenth-century documents, Dahar al-Omar built warehouses at the harbor and renovated the southern breakwater and the Island of Flies. The renovation was carried out using fieldstones bonded with cement into which ancient columns were inserted, to which ships could moor. In the second half of the eighteenth century the Akko Harbor flourished as an important Eastern Mediterranean trade center, frequented by Ottoman, Russian and French ships. In April 1799, the French expeditionary force under Napoleon Bonaparte reached the gates of Akko after conquering Jaffa and Ramla. The French army tried for a month to breach the walls of the city and conquer it, but to no avail. During the siege, the defenders of Akko were assisted by the British fleet under the command of Vice-Admiral Sidney Smith. This fleet effectively stopped any French attempt to bring in reinforcements by sea; it even captured a number of French vessels carrying cannons from the siege on Jaffa. In May, the French forces withdrew southward by land via the coast. Contemporary French sources provide an abundance

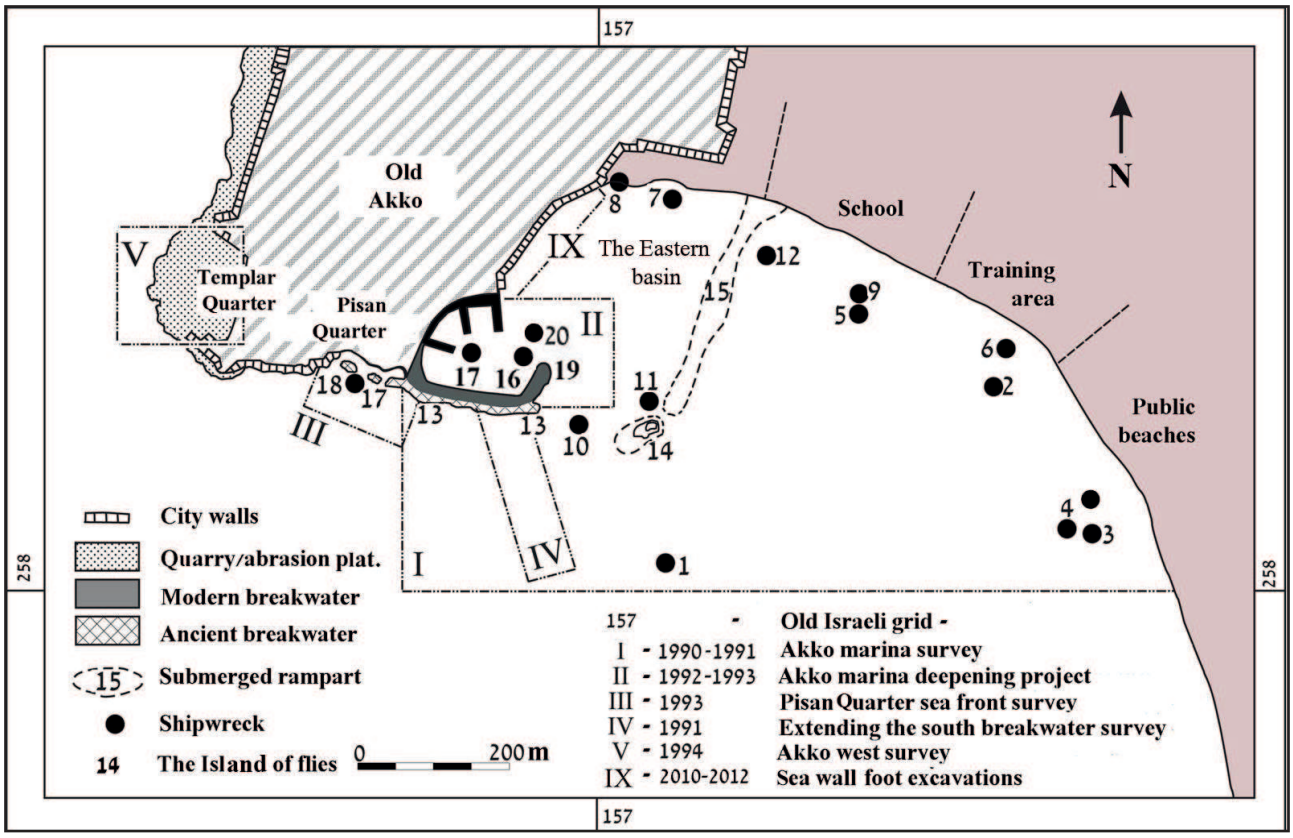

Fig. 2: Map of the various underwater surveys conducted by the IAA in and around the Akko Harbor, 1990–2012, and the main archaeological remains (IAA).

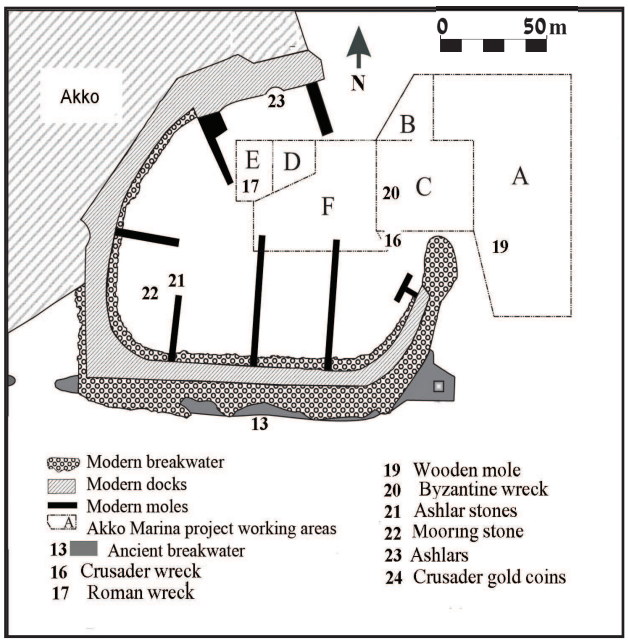

Fig. 3: Map of work areas of the Akko Marina project, 1992–1993 (IAA)

of maps and descriptions of the array of British and French forces. In the mid-nineteenth century the harbor began to fill with silt and declined in importance.

History of Research – Underwater Excavations and Surveys at Akko, 1960s–2004

Several underwater archaeological activities were carried out in Akko since 1960 by various researchers and institutions. Underwater archaeological activities can be divided into a number of categories: pre-development rescue excavations and/or surveys (aimed at studying, documenting and, if possible, rescuing archaeological finds in areas intended for destructive, modern development); rescue excavations and surveys associated with the deepening of the modern marina by heavy dredging machinery; research excavations; and didactic excavations (aimed at training students in underwater archaeology). Below is a review of the main underwater surveys and excavations carried out in Akko from the 1960s to 2004.

Underwater Pre-development Rescue Surveys and Excavations at the Southern Breakwater and Island of Flies

From 1964 to 1966, the Underwater Exploration Society of Israel conducted underwater excavation and survey prior to the construction of Akko's modern marina. The expedition, headed by E. Linder, examined the foundations of the Island of Flies, the

southern breakwater and the remains of shipwrecks at the entrance to the harbor. Test excavations were conducted in 1966 at the eastern rampart (Fig. 2: 15) and southern breakwater (Fig. 2: 13) and at the Island of Flies (Fig. 2: 14). A sub-bottom profiler sonar survey and proton magnetometer survey were also conducted around Akko and the various phases of construction of the harbor were reconstructed (Raban 1982a, 1982b; Linder and Raban 1964; Flinder *et al.* 1993; Raban 1983, 1993). Two wooden hulls of shipwrecks were discovered and checked (Fig. 2: 10, 11).

Training Excavation of a Shipwreck

In 1975 E. Linder of the University of Haifa and J.R. Steffy of Texas A&M University conducted a training excavation (in the course of a field school) of a shipwreck on the north side of the Island of Flies (Fig. 2: 11). The wooden hull of the ship was uncovered, containing copper alloy nails, along with a large quantity of schist stones used as ballast. In 2006, the University of Haifa renewed the excavation of this ship.

Underwater Research Survey of the Southern Breakwater

In the 1980s, R. Gertwagen of the University of Haifa conducted an underwater survey of the eastern end of the southern breakwater. Another survey and a test excavation were undertaken in the area of the Pisan Quarter of the Crusader period, in the so-called "Pisan Harbor" (Fig. 2: III) (Gertwagen 1989, 1996).

Underwater Rescue Surveys – the 1983 Deepening of the Akko Marina, 1991-1992

From 1983 to1988, during and after the deepening of the marina, an underwater survey was carried out by E. Galili of the University of Haifa and S. Wachsmann of the IAA. The survey, which examined the material removed by the dredger that deepened the marina, revealed a few dozens pottery and metal objects. Also documented were finds retrieved by fishermen-divers in the areas where the dredged materials were deposited.

Underwater Surveys Prior to Planned Expansion of the Akko Marina

In 1988, a plan to expand the Akko Marina was submitted for approval by the IAA. The plan included significant expansion of the marina to the south and east, including reclaiming underwater areas and the construction of a residential neighborhood. An underwater survey was undertaken during 1991-1992 by the IAA in the areas intended for development (Fig 2: I). A sonar survey, a metal detection survey and water-jet drillings were conducted as well. Remains of thirteen shipwrecks were detected and examined during the survey (Galili *et al.* 1991, 2002; Galili and Sharvit 2002; Galili this volume f: fig. 1) (Fig. 2).

Underwater Rescue Survey in the Akko Area 1990–2004

The IAA conducted year-round underwater rescue surveys whose purposes were to locate, document and rescue findings uncovered on the sea bed that were at risk of destruction or theft.
The surveys were carried out along the entire

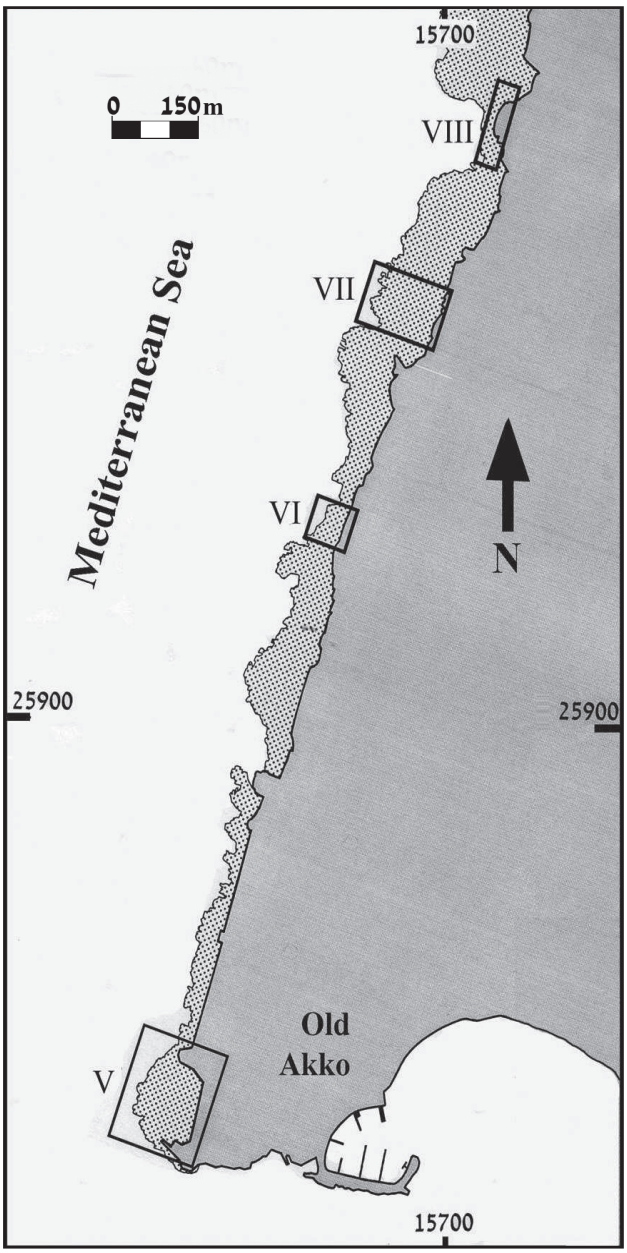

Fig. 4: Map of the underwater and coastal surveys by the IAA on the west coast of Akko (IAA)

Mediterranean coast of Israel and inland waters. Priority was given to areas where there was a high likelihood of exposure, destruction or looting of finds. During the ongoing surveys in the Akko area, remains of ships (mainly anchors, nails and lead sheathing), weapons, ammunition and cargos were found. In addition valuable information was gathered from fishermen-divers and others with regard to items found at sea during diving and fishing (Galili 1987; Galili *et al.* 2002, 2004; Galili and Rosen 2008a, 2008b).

Underwater Rescue Survey prior to the Extension of the Southern Breakwater, 1991

Following a plan to extend the southern breakwater by 200 m, an underwater survey was carried out along the zone of the planned extension. The survey, which included scans of the seabed by divers and water-jet drillings, was carried out by the IAA (Galili and Sharvit 2002, Fig. 2: IV).

Underwater Pre-development Survey – the Pisan Quarter Seafront, 1993

Following a plan to build a bridge connecting the fishing harbor with the western sea wall promenade, underwater survey was carried out south of the Pisan Quarter (Fig. 2: III). The survey was carried out by the IAA (Galili *et al.* 2002).

Underwater and Coastal Pre-development Rescue Survey, Southwestern Akko, 1994–1995

In the framework of planning tourist accommodations in Akko, the possibility of building a hotel on the abrasion platform and the ancient quarry north of the lighthouse was assessed (Figs. 2: V, 4: V). An underwater and coastal survey was carried out by the IAA (Sharvit and Galili 2002). Finds included ancient quarries, the foundations of city walls and fragments of walls that were built on the coastal abrasion platforms. In that area, according to historical documents and drawings, the castle of the Templar military Order was located during the crusader period (Galili and Sharvit 2002; Sharvit and Galili 2002; Galili this volume e).

Underwater Western Akko Pre-development Rescue Survey, 2003/2004

A coastal and underwater survey was conducted on the *kurkar* abrasion platforms at the western and northern beaches ahead of construction of the beach promenade and the laying of drainage pipes. These surveys included mapping of quarries and ancient installations by means of differential GPS and manual measurement of the abrasion platforms. The surveys revealed two millstone quarries (Fig. 4: VII, 4: VIII), a quarry for building stones (Fig. 4: V) and small rock-cut pools (Fig. 4: VI). (Galili and Sharvit 2002; Sharvit and Galili 2002).

Underwater Pre-development Survey – the Pisan Quarter Seafront, 2004

In order to protect the sea walls and ancient structures on the shoreline of the Pisan Quarter, ancient submerged structures were surveyed and mapped. The survey included bathymetric mapping of the seabed with the assistance of the Israel Electric Corporation, water-jet drillings, a surface survey and mapping of the remains of the ancient breakwater (Fig. 2: III, Galili this volume e). The surveys were by the IAA (Galili and Sharvit 2002; Galili *et al.* 2010: figs. 17.2, 18).

The Akko Marina Archaeological Project, 1992–1993

The findings from this project form most of the material presented in this volume. The archaeological project accompanied the deepening of the Akko Marina from November 1992 to June 1993 and also included salvage surveys conducted by the IAA

Fig. 5: The dredger that deepened the marina (J. Galili)

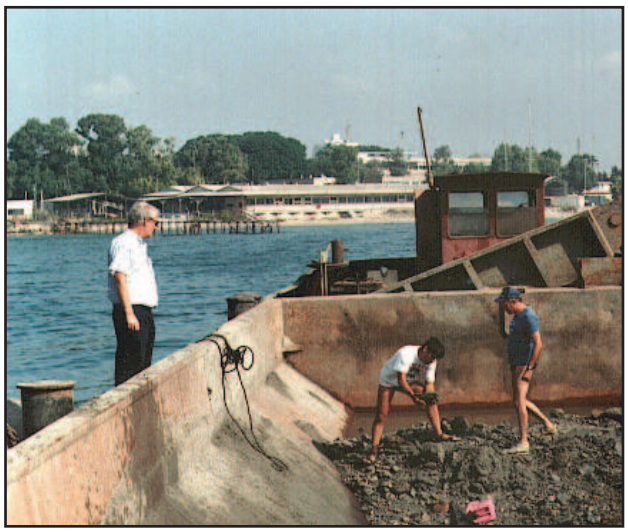

Fig. 6: Preliminary examination of the material removed from the marina by a barge that ferried it to the deposit sites at sea (J. Galili)

in the Akko region from 1990 to 2004 (see above) (Figs. 2: II, 3). The Akko Marina was deepened so that it could serve water craft with a draft of several meters (Galili and Sharvit 2002; Galili and Rosen 2008a; Galili *et al.* 2010). Some 15,000 cubic m of material were dredged from the marina on behalf of the Shipping and Ports Department and the Tourism Ministry. The IAA archaeological work, directed by E. Galili, included ongoing supervision of the dredging and survey dives during which ancient remains on the marina bed were located, mapped and retrieved. The material dredged from the marina was examined by divers at the dumping areas (see below).

Rescue Excavations at the Foot of the Southeastern City Wall, 2008–2012

In order to expose and repair the foundation of the Ottoman southeastern sea walls of Akko, which were damaged by marine erosion, a 250m section was excavated at the foot of the walls (Fig. 2: VI). The excavations, carried out by the IAA, the Old Akko Development Company and Rhodes University, revealed installations associated with the Early Roman-Hellenistic harbor and shed light on the foundation methods of the Ottoman city walls (Sharvit *et al.* 2013).

Methodology

To map the location of the archaeological finds, the marina area was divided into 132 squares (10 × 10m each). Each group of squares marked a defined excavation, which was allotted its own separate deposit site in the open sea. The deposit sites were marked by numbered buoys. The area of the marina was divided into six main work areas, each of which included a number of squares (Fig. 3). A – east of the marina; B – northeast of the entrance to the marina; C – entrance to the marina; and D, E and F – inside the marina. The deepening of the marina was carried out by a bucket-dredger, based on a barge, which raised sediment from the marina bed and loaded it into a discharge barge (Figs. 5, 6). Preliminary examination of the material was done aboard the barge, and finds identified were collected. Each barge received an identifying number connecting it to the various excavation areas in the marina. The sediment, including the archaeological material, was deposited into pre-determined, rocky flat-bottomed locations, at a depth of 15–20m in the open sea. The dumping was planned to avoid ecological damage to the marine environment and according to a special permit issued by the Environmental Protection Ministry. The deposit sites were surveyed by divers and examined by a metal detector. Indicative findings were collected and taken ashore. A data base was prepared coordinating the work areas in the marina and the numbers of the barges depositing the material into the sea. Findings retrieved from the sea were soaked in fresh water for several days. They were then dried and marked with the number of the barge that had retrieved them, so the area of the marina were they were found could be identified. All told, the contents of some 80 barges were deposited in the open sea; approximately 100 dives were made at the deposit sites and some 30 dives in the marina. Divers mapped the submerged installations in the marina by means of measuring tape and compass, and the data was recorded on site. Later the data was transferred to the graphic journal. The mapping of the marina and the identification of the work squares and the excavation areas were made by compass binocular and a laser rangefinder, using known reference points on the shoreline. Buoys were placed at points where remains to be preserved had been identified, and dredging in those areas was halted.

Underwater Rescue Surveys

These surveys, whose purpose was to document and salvage ancient remains exposed on the seabed and at risk of destruction or looting, were carried out mainly after winter storms. Priority was given to areas where the risk of exposure and looting was greatest. Pairs of divers working from a boat surveyed the seabed using a compressed air system, measuring equipment, sketching and photography, and, frequently, a hand-held metal detector. Sites were initially located and mapped manually (see below) and, beginning in the 1990s, by GPS.

Sonar Scanning of the Seabed

To locate the remains of ships, cargos and structures underwater, the project was assisted by the Israel Oceanographic and Limnological Research Institute using ground-penetrating sonar to scan various parts of the marina and its surroundings. The survey was carried out by a boat towing a submerged sonar transmitter that sent acoustic waves to the seabed. The reflected acoustic waves were received by a hydrophone and transferred to a recorder that recorded on paper profiles and anomalies that might be ancient structures or shipwrecks. Targets located were marked by buoys and the seabed at these points was then checked by divers and water-jet drillings (see below). Navigation of the boat and mapping of the profiles and the targets were carried out by means of a Mini Ranger with the assistance of two points on the beach where transmitters had been installed to broadcast signals to the receiver on the boat and record its location at any given moment.

Underwater Electromagnetic Scanning

To locate large metal objects, such as cannons or heaps of sherds containing large ferrous concentrations, a proton magnometer was used operating together with ground-penetrating sonar. The equipment measured and mapped the magnitude of the magnetic field of the areas where the boat passed. A map of magnetic field values was produced showing magnetic anomalies, where the likelihood was high of finding large metal objects or cargos of pottery. The experimental stage revealed numerous anomalies in and around the marina, originating in scrap metal. These scraps made the work difficult; thus magnetic mapping was not fully implemented and it was decided to rely mainly on the ground-penetrating sonar and diving surveys.

Water-jet Drilling

This method utilized a metal pipe inserted into the seabed through which a jet of water was ejected. A pump on the diving boat pumped in sea water and conveyed it by means of a flexible tube to the metal pipe inserted by divers into the seabed. By the nature of the sediments emerging from the drilling and the meter mark on the metal pipe, the divers recorded the depth of penetration and the nature of the subsurface of the seabed at each drill site. Water-jet drilling was utilized at points where the ground-penetrating sonar identified targets that seemed to be ancient remains. This method was also used in areas where information was required about the seabed subsurface for planning of a system of structures intended to protect the sea walls and the ancient remains in the Pisan Quarter seafront.

Mapping

Bathymetric underwater mapping was done by the Israel Electric Corporation's Marine Biology Department, utilizing a differential satellite navigation system and sonar equipment synchronized by computer. The equipment was installed on a boat moving back and forth as it mapped the area south of the Pisan Quarter. The mapping served to plan the protection of the sea walls and document the submerged remains of the ancient breakwater in this area, which were *in situ* there and had not been covered by the stones of the modern breakwater. The coastal mapping of the sea walls and the ancient installations on the shoreline in the western part of the marina and in the Pisan Quarter were implemented using the differential satellite navigation system. Remains of shipwrecks and harbor installations in shallow water were identified by aerial photographs.

Test Excavations

Small probes (1 × 1m) using water-jet drilling were made in and around the marina, particularly in places were remains were located under the seabed.

Registration of Finds

The finds retrieved during the deepening of the marina and during the surveys in the deposit areas off shore were marked with the number of the dumping barge, the number of the working area in the marina and the item number. The finds were also given categories according to groups demonstrating their function. A few items retrieved during surveys before or after the dredging project were marked by the usual method for underwater rescue surveys of the IAA; these were given the number of the dive report, which includes: permit number (top), report number (bottom left in a triangle) and item number (bottom right).

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