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Dendroarchaeology of Shipwrecks in Israel

Abstract

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Comprehensive dendro-archaeological studies carried out on nine shipwrecks along the Mediterranean coast of Israel enable to identify the various wood species used in ancient shipbuilding in the Eastern Mediterranean, to detect the repairs and locate the possible construction sites of the ships.

Ma'agan Mikhael and Tantura Lagoon shipwrecks: The earliest ship (the Ma'agan Mikhael) presents the Classical Period, dated to the 5th century BC. About 80% of the hull timbers were made of *Pinus brutia* (Calabrian pine) and the remaining components of the hull were made of tree species native in west – northwestern Turkey.

Three ships present the Medieval Period: Dor 200/1 dated to the 5th -6th centuries AD, Tantura E dated to the 7th-9th centuries AD, and Tantura F dated to the beginning of the 8th century AD. The wood species used for building the hull of Dor 2001/1, i.e. *Pinus brutia*, *Cupressus sempervirens* (Cypress) and *Fagus orientalis* (Oriental beech) are native to west – northwestern Turkey, except for *Tamarix* (X5) (Tamarisk) and *Ziziphus spina-christi* (Christ thorn; Jujube) which are native to Israel and were used as repairs on the ship made upon its arrival at Dor. Tantura E was built mainly of *Pinus brutia* and *Cupressus sempervirens*, whereas *Tamarix* (X5), which is native to Israel, was used as repairs on the ship upon its arrival at Dor. Two wood species used in constructing the hull of Tantura F, i.e. *Pinus brutia* and *Tamarix smyrnensis*, grow together native in two regions in Turkey: around Izmir and in Antalya, suggesting that most likely it was built on the western or southern coast of Turkey.

Three ships, Dor 2002/2, DW2 and Dor C dated to the 17th-19th centuries AD present the Post Medieval Period (Ottoman). The hull of those ships was mainly constructed of *Pinus brutia* which constituted 80%-85% of the examined timbers. The assemblage of wood species used in constructing the hull of those three ships grow native in west – northwest Turkey, suggesting that they were probably built in this region.

Akko shipwrecks: Akko 1 and Akko 2, dated to the 18th-19th centuries AD, present the Post Medieval Period (Ottoman). Akko 1 was mainly built of *Quercus petraea* (Sessile oak) constituting about half of the timbers, *Quercus cerris* (Turkey oak) and *Pinus brutia*. Akko 2 was built only of *Pinus brutia*. The native habitats of the tree species used in constructing the hull of those two ships suggest they were probably built in west – northwest Turkey.

Introduction

Comprehensive dendro-archaeological investigation of ancient shipwrecks in Israel has started several years ago and the results of the detailed analyses turned to be an integral part of shipwreck studies. Wood samples taken from various hull components are best pre-

served when kept in sea water until their examination in the laboratory, avoiding deformation of the anatomical wood structure, and enabling an accurate identification up to the species level of the hull construction timbers (Liphschitz 2007).

The paper presents the detailed studies of nine shipwrecks from the Mediterranean coast of Israel, which sank at three sites: one at Ma'agan Mikhael, six at Tantura Lagoon (Dor) and two at Akko bay. One shipwreck is from the Classical period, three shipwrecks represent the Medieval period and five shipwrecks represent the Post Medieval period.

Cross and longitudinal, tangential as well as radial sections, were made with a sharp razor blade for each sample, stained with Safranin and preserved in Glycerol. The identification of the wood up to the species level was based on the three dimensional structure of the wood as seen microscopically in those sections. Comparison was made with reference sections, prepared from systematically identified, living trees and shrubs, and with anatomical atlases.

Assumptions concerning the possible construction areas of these shipwrecks are based on the native distribution of the various tree species used in the construction of these hulls. Use of repairs on a ship can be inferred from the presence of "foreign" timbers, made of trees originating at a different geographical region than most of the vessels' construction timbers, pointing to a damage caused to the vessel either on its route or on its arrival site.

Fig. 1. Ma'agan Mikhael shipwreck.

Table 1. Tree species used in the hull construction of Ma'agan Mikhael shipwreck.

Tree species	Components	No. of samples
Pinus brutia	planks, frames, keel, stringers, mast - partner beam, mast step, stanchion, stern knee, bow knee	97
Quercus coccifera	tenons, anchor	17
Quercus pubescens/Q. petraea	false keel	2
Fraxinus excelsior	peg	1
Fagus orientalis	tenon	1
Cornus sanguinea	part of anchor	1
Total samples examined		119

The Classical Period shipwreck from Ma'agan Mikhael (5th century BC)

The Classical (Persian) period ship was discovered 70 m off shore of Kibbutz Ma'agan Mikhael, ca. 30 km south of Haifa. It was submerged in less than 2 m of water and buried under 2 m of sand. It was a small cargo vessel, about 13.5 m long. The ship was dated to the late 5th century BC (Kahanov 2003). A substantial portion of the wooden hull structure survived in a good state of preservation and conserved with Poly Ethylene Glycol (PEG) (Linder 1991).

Altogether 119 samples were examined (Table 1). They were taken from various parts of the hull ship: keel, false keel, frames, planks, stem, sternpost, false sternpost, bow and stern knees, tenons, pegs, mast step, mast-partner beam, stringers, stanchion and anchor parts. The hull was made of seven woody species: *Pinus brutia* (Corsican pine), *Cornus sanguinea* (Common dogwood), *Fagus (*aff. *orientalis)* (Oriental beech), *Fraxinus excelsior* (Common ash), *Quercus coccifera* (Holly oak) and *Quercus pubescens* (Downy oak)/ *Quercus petraea* (Sessile oak) (Liphschitz 2004a, 2004 b; Liphschitz & Pulak 2007/8).

The majority of the hull timbers were of *Pinus brutia* (81.5%). All timbers of the ship were made from trees, which grow native mainly in west - northwestern Turkey, thus pointing to the site where the ship was constructed.

The Tantura Lagoon (Dor) - The Medieval Period ships from Dor: The 2001/1 shipwreck from the 5th Century AD

Dor 2001/1 was probably a Byzantine coaster carrying building stones, dated to the end of the 5th or beginning of the 6th century AD. It was found about 70 m offshore at a sea depth of 1 m and buried under 1.8 m of sand. Its total length of the finds was 11.5 m and its maximum width was 4.5 m (Mor & Kahanov 2006).

Altogether, 202 samples were taken and identified, representing the keel parts, false keel, planking, ceiling, frames, chine strake, central stringers, planks, wale, mast step sis-

Table 2. Tree species used in the hull construction of Dor 2001/1 shipwreck.

Tree species	Components	No. of samples
Pinus brutia	planks, ceiling, frames,	42
Cupressus sempervirens	keel, planking, central stringers	
	chine strake, wales, mast step sister	54
Quercus cerris	frames	7
Quercus coccifera	frames, false keel	9
Fagus orientalis	frames	39
Ulmus campestris	frames, end post	18
Ziziphus spina christi * (repairs)	frames	17
Tamarix (X5) * (repairs)	frames	16
Total samples examined		202

ter and end post (Table 2). In this ship, the timber was taken from *Pinus brutia, Cupressus sempervirens, Fagus orientalis, Ulmus campestris, Quercus coccifera, Quercus cerries, Ziziphus spina christi* and *Tamarix (X5)* (Tamarisk) (Liphschitz & Pulak 2007/8).

All tree species are native to west – northwestern Turkey, except for *Ziziphus spina christi* and *Tamarix (X5)* which are native to Israel, and were used for repairs on the ship, made on its arrival at Dor.

Tantura F shipwreck from the 8th century AD

Tantura F ship is dated to the beginning of the 8th century AD (local early Islamic Umayyad period). The shipwreck was discovered in 1996 during a survey at Dor (Tantura Lagoon) about 70 m offshore in 1 m of water, buried under additional 1.5 m sand. The archaeological remains covered an area of 12×3.5 m (Wachsman & Kahanov 1997; Barkai & Kahanov 2007). Altogether 137 wood samples were identified from Tantura F shipwreck. The samples were taken from keel, frames, planks, stringers, mast step and central longitudinal timbers, matting and a twig (Table 3) (Liphschitz & Pulak 2007/8),

The hull was constructed (except for a piece from the keel) of two tree species: *Pinus brutia* (55%) and *Tamarix smyrnensis* (tamarisk of diffuse porous wood, and 5 sepals, petals and stamens) (44.5%). Both tree species grow native together in two regions in Turkey: in Izmir in west Turkey and in Antalya in south Turkey (Davis 1965-82). One piece from the keel was made of *Pinus nigra*.

Tantura E shipwreck from the 7th-9th centuries AD

Tantura E shipwreck was located about 25 m offshore in a water depth of 2.5 m. Radiocarbon dated the wreck between the end of the 7th and the beginning of the 9th cen-

Table 3. Tree species used in the hull construction of Tantura F shipwreck.

Tree species	Components	No. of samples
Pinus brutia	frames, stringers, keel section, planks, mast step assemblage	75
Pinus nigra	keel section	1
Tamarix smyrnensis	frames, central longitudinal timbers	61
Total samples examined		137

turies AD (the early local Islamic period). Its measured length was ca. 7.2 m and its width was ca. 3.1 m but its estimated length varied between 12m to 15 m (Royal & Kahanov 2000; Planer 2007; Kahanov & al. 2008).

Altogether 103 samples were collected and identified, including keel, keelson, end post, frames, strakes, stringers, ceiling planking and stanchion. The hull timbers were made of *Pinus brutia*, *Cupressus sempervirens, Tamarix (X4), Tamarix (X5), Quercus coccifera, Quercus cerris, Ulmus campestris* and *Fraxinus excelsior* (Table 4). All hull construction timbers were made of trees which grow native mainly in west - northwestern Turkey.

The Post Medieval (Late Ottoman) Period Ships from Dor: Dor C shipwreck from the 17th-19th centuries AD

Dor C is a Late Ottoman (17th-19th century AD) shipwreck lying off Dor. Excavations started for the first time on the year 2000. The hull was completely buried in sand. The wreck is 16 m from stem to sternpost (Bowen 2001). On 2008 another excavation season

Table 4. Tree species used in the hull construction of Tantura E.

Tree species	Components	No. of samples
Pinus brutia	planks, stringers, frames	39
Cupressus sempervirens	keel, ceiling planking, stringers, false keel, keelson, planks, stanchion, end post	24
Tamarix (X5)	frames, keel section	29
Tamarix (X4)	frames	3
Quercus coccifera	frames	2
Quercus cerris	frame	1
Ulmus campestris	frame	1
Fraxinus excelsior	frames	4
Total samples examined		103

Table 5: Tree species used in the hull construction of Dor C shipwreck.

Tree species	Components	No. of samples
Pinus brutia	ceiling planking, wales, frames, mast step, mast, stanchion	79
Pinus nigra	stemson	1
Quercus coccifera	treenails	2
Quercus cerris	treenail, keel	3
Corylus colurna	treenail	1
Ulmus campestris	apron	1
Total samples examined		87

was carried out (Kahanov & al. 2008) and 87 wood samples were taken for wood identification from ceiling planking, planks, frames, wales, stem, keel, stemson, mast, mast step, apron, stanchion and treenails. The excellent state of preservation of the wood is also evident in its hardness.

All ceiling planking, frames, wale, stem, mast and mast step and stanchion were made of *Pinus brutia* which constituted 85% of the hull timbers examined. The keel and treenails were made of *Quercus cerris,* and other treenails were of *Q. coccifera*. The stemson was of *Pinus nigra*, the apron was of *Ulmus campestris,* and another wooden nail from the keel was made of *Corylus colurna* (Table 5). The native distribution area of the assemblage of wood species used in the construction of the hull is in west – northwestern Turkey, suggesting that the ship was probably built in this region.

DW-2 shipwreck from the 17th-19th centuries AD

The DW2 shipwreck was found in the southern lagoon of Dor beach, at a depth of less than 2 m. Its estimated length was 15.5 m and it was dated to the 17th-19th century AD (Late Ottoman period) (Yovel 2005).

Altogether 63 wood samples were identified. The samples were taken from keel, frames, planking, floor timbers and treenails. Most wooden parts (96%) were made of *Pinus brutia*. Three nails were made of *Quercus coccifera* and one nail was made of *Q. cerris* (Table 6) The assemblage used in the construction of the hull grow native in west-northwestern Turkey, suggesting the ship was probably built in this region (Liphschitz 2004a; Liphschitz & Pulak 2007/8).

Dor 2002/2 shipwreck from the 17th-19th centuries AD

Dor 2002/2 shipwreck was discovered on the shore line, ca. 30 cm below sea level. It was dated by 14C AMS to the 17th-19th century AD (Late Ottoman period) (Cvikel 2005).

Table 6. Tree species used in the hull construction of DW2 shipwreck.

Tree species	Components	No. of samples
Pinus brutia	frames, keel, planking, floor timbers	59
Quercus coccifera	treenails	3
Quercus cerris	treenail	1
Total samples examined		63

The excellent state of preservation of the wood and the existence of a metal cable in the shipwreck suggest that it is a late Ottoman vessel.

Altogether 27 samples were collected and identified. They included timbers from planks, frames and treenails. Most of the timber (81%) was made of *Pinus brutia*. Other species identified were: *Quercus coccifera, Quercus cerris* and *Pinus nigra* (Table 7) (Liphschitz 2004a; Liphschitz & Pulak 2007/8). The timbers of the ship grow native together in west – northwestern Turkey, where most probably this ship had been built (Liphschitz & Pulak 2007/8).

Akko (Acre) Bay:

Akko 1 shipwreck from the 17th-19th centuries AD

The Akko 1 shipwreck is located 30 m north of the Tower of Flies at depth of 4 m. The shipwreck is 23 m long and 4.38 m wide. It was dated to the 17th-19th centuries AD (Kahanov & al. 2008; Cvikel & Kahanov 2009).

Altogether 293 samples for wood identification were taken from the keel, false keel, frames, stem, false stem, planks, ceiling planking and apron. The hull timbers were mainly made of *Quercus petraea/Quercus pubescens* (61%)*, Quercus cerris* (19%) and *Pinus brutia* (15%). The false keel was made of *Fagus orientalis*. Three other components were of *Ulmus campestris, Acer pseudoplatanus* and *Tamarix (X5)*.

Table 7. Tree species used in the hull construction of Dor 2002/2 shipwreck.

Tree species	Components	No. of samples
Pinus brutia	planks, frames, treenail	22
Pinus nigra	treenail	1
Quercus cerris	plank	2
Quercus coccifera	plank, treenail	2
Total samples examined		27

Table 8. Tree species used in the hull construction of Akko 1 shipwreck.

Tree species	Components	No. of samples
Pinus brutia	frames, planks, ceiling planking	43
Quercus petraea/Q. pubescens	frames, false stem, planks	180
Quercus cerris	keel, frames, stem, wale, apron, ceiling planking	56
Quercus coccifera	frames	10
Fagus orientalis	false keel	1
Ulmus campestris	plank	1
Acer pseudoplatanus	plank	1
Tamarix (X5)	frame	1
Total samples examined		293

Akko 2 shipwreck from the 17th-19th centuries AD

Akko 2 shipwreck is located 50 m to the north of Akko 1shipwreck, in water depth of 3 m. It is approximately 16 m long and served as a lighter or a small coater. It was dated to the 17th-19th centuries AD (Kahanov & al. 2008). Altogether 49 wood samples were taken and identified. All hull timbers examined, including planks and a keel, were made of *Pinus brutia* (Table 9).

Conclusions

The determination of wood species used in constructing the hulls of these ships enables identification of possible regions where each vessel was built. The hulls of eight ships, dated to the Classical period (Ma'agan Mikhael), Medieval period (Dor 2001/1, Tantura E) and Post Medieval period (Dor C, Dor 2002/2, DW2, Akko 1, Akko 2), were mainly constructed of *Pinus brutia, Quercus coccifera, Q. cerris and Q. petraea/Q. pubescens*. The habitat where all four tree species, as well as other species used in their hull construction, grow native in west – northwestern Turkey (Tables 10-11), thus pointing to this region as the area where these ships were most likely built. One ship of the Medieval period (Tantura F) was built of *Pinus brutia* and *Tamarix smyrnensis* which grow native together either in Izmir in west Turkey or in Antalya in south Turkey. Certain timbers that grow native on the Israeli coast found in one ship (Dor 2001/1) were probably used for repairs due to damage caused to the vessel on its arrival to the Israeli coast.

Table 9. Tree species used in the hull construction of Akko 2 shipwreck.

Tree species	Components	No. of samples
Pinus brutia	planks, keel	49

Table 10. The native habitats in Turkey of tree species used in the hull of 9 Israeli shipwrecks (from: Davis, 1965-1982).

Tree species	Location in Turkey
Pinus brutia	Outer Anatolia, Turkey in Europe &Islands
Fagus orientalis	N. Turkey & scattered in N. & W. Anatolia
Quercus coccifera	N. & W. Turkey, S. Anatolia & Islands
Quercus cerris	Throughout Turkey, except N.E. & E. N.W. Turkey
Quercus petraea/	
Quercus pubescens	N. Turkey, e. & W.Anatolia
Cornus sanguinea	N.W.Anatolia, C.& S. Anatolia
Fraxinus excelsior	N. Anatolia
Ulmus campestris	N.W.Turkey & adjacent, N.E. Anatolia
Cupressus sempervirens	Antalya, Taurus and Islands
Tamarix smyrnensis	Izmir, Antalya

Table 11. The distribution in the world of the tree species used in hulls of examined shipwrecks (from: Davis 1965-1982).

Tree species	Native distribution in the world
Pinus brutia	Turkey, S. Italy, Crimea, W. Syria, N. Iran, W. Caucasus
Fagus orientalis	Turkey, Bulgaria, Romania, Greece, Crimea, Caucassus
Quercus coccifera	Turkey, France (Gallia-Nabonensi), Peleponese, Spain
Quercus cerris	Turkey, Central Europe, Austria, South-Central Europe
Quercus petraea	Turkey, Balkans, Caucassus, N. Iran
Quercus pubescens	Turkey, West Europe, Central Europe, Crimea,
Cornus sanguinea	Turkey, Central Europe, South-East Europe, Russia, Crimea, l
	S. Asia
Fraxinus excelsior	Turkey, Caucassus, N. Iran
Ulmus campestris	Turkey, Greece, Trace
Cupressus sempervirens	Turkey, Cyprus, Crete
Tamarix smyrnensis	Turkey

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