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Analysis of Fish Bones from the Tantura F Shipwreck, Israel

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ABSTRACT: Underwater excavations of the Tantura F shipwreck in the Dor/Tantura lagoon, Israel, which dated to the local early Islamic period, exposed the remains of amphorae with tens of thousands of fish remains. Taxonomic identification exhibited the preponderance of tiny cichlids (Cichlidae). Moreover, elements of the entire skeleton were represented in the assemblages. We therefore concluded that the amphorae were probably filled with fish sauce. We discuss the possible origins of the fish sauce, whether local or imported. These finds are important as they provide clear evidence that Dor was populated during the Islamic period and probably continued to be an important port along trade sea routes.

KEYWORDS: CICHLIDAE, EARLY ISLAMIC PERIOD, FISH SAUCE, FISH PROCESSING, MARITIME TRADE, ISRAEL

RESUMEN: Excavaciones subacuáticas llevadas a cabo en el pecio de Tantura F, en la laguna costera de Dor/Tantura en Israel, y datadas en el periodo islámico temprano, evidenciaron la presencia de docenas de miles de restos de peces dentro de ánforas. La identificación taxonómica reveló la dominancia de diminutos cíclidos (Cichlidae) de los que la totalidad de los elementos del esqueleto apuntan a la presencia de ejemplares completos. Al parecer, las ánforas transportaban algún tipo de salsa de pescado, de la que desconocemos su carácter si local o importado. Estos hallazgos son importantes al demostrar que Dor estuvo ocupado durante el arranque del período islámico manteniendo seguramente su condición de núcleo de referencia en las antiguas rutas de navegación marítima.

PALABRAS CLAVE: CICHLIDAE, PERIODO ISLÁMICO TEMPRANO, SALSA DE PESCADO, PROCESADO DE PESCADO, RUTAS MARÍTIMAS, ISRAEL

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INTRODUCTION

The Tantura F shipwreck was discovered in 1996 during a survey by a combined expedition headed by S. Wachsmann of the Institute of Nautical Archaeology at Texas A & M University (INA) and the Recanati Institute for Maritime Studies at the University of Haifa (RIMS) (Wachsmann *et al.*, 1997). This shipwreck was found in Dor (Tantura) lagoon, which is located on the Mediterranean coast of Israel, south of ancient Tel Dor and about 13 km north of Caesarea (Figure 1).

The wreck site was about 70 m offshore at a depth of approximately 1 m and was covered by ca. 0.85 m layers of sand. Tantura F was excavated over five seasons from 2004 to 2008 by RIMS under the direction of Y. Kahanov, together with the Nautical Archaeology Society of Great Britain (NAS) headed by C. Brandon, and K. Raveh of the local Aqua Dora diving center (Barkai & Kahanov, 2007). Based on both ^{14}C dates and ceramic typological analysis, the shipwreck was dated to have occurred between the mid-7th and the end of the 8th centuries C.E., or the local early Islamic period (Barkai *et al*., 2010).

From the extant hull remains that spread over 11.7 x 3.24 m, the ship was reconstructed as a coaster or a fishing vessel that was about 15.7 m long. The archaeological finds included remains of pottery (Barkai *et al*., 2010), two iron anchors (Eliyahu *et al*., 2011), rope, reed matting, two baskets, a wooden spoon, a bone needle, and a wooden ring. The botanical and faunal remains included olives, carobs, dried nuts, and a large number of fish remains. The latter were recovered in two different types of depositions: 1) fish skeletons accumulated in the vicinity of baskets (Figure 2); and 2) tiny fish bones recovered in eight amphorae (Figure 4). In this paper, we discuss the fish remains recovered in the amphorae in regard to taxonomic identification and origin.

FISH SAUCE PRODUCTION

Fish sauce had an important role in Roman cuisine. Curtis (1984, 1991, 2009) identified four different types of fish sauces produced by the Romans: garum, liquamen, allec, and muria.

Garum was the primary sauce produced by the hydrolysis of small whole fish or fish innards in the presence of salt through natural fermentation over several months. The solid fish material remaining from garum production was called allec. Muria was the salty solution that resulted from osmosis during the salting of whole, gutted fish or sliced fish (salsamentum). The precise nature of liquamen remains obscure, but, based on modern parallels, it seems to have been the result of subsequent washings of allec with a salty solution. As such, liquamen was closely related to garum, and its similar production process explains why in late antiquity the term liquamen effectively replaced garum as the generic term for fish sauce.

In general, Romans placed into a vat small fish, particularly anchovies, sardines, and mackerel, and added salt at prescribed ratios and sometimes various herbs, spices, or wine. They used weights to press down on the concoction, covered it, and allowed it to remain in the sun for several months. At the end of this time, they collected the liquid garum by using a basket, filtered it, and placed it in a terra-cotta transport vessel, or amphora (Curtis, 1991, 2009: 713s).

MATERIALS AND METHODS

Large numbers of small-sized fish remains (ca. tens of thousands) were recovered embedded in residue inside the bases of eight «bag-shaped» ovoid amphorae (Figure 3). The type and origin of the amphorae were studied from their typological aspects. Petrography and chemical analysis were performed by S. Klein of the Institute for Mineralogy, Goethe University, Frankfurt, Germany. The matrix inside the amphorae was examined for lipids and residue (B. Stern at the Department of Archaeological and Environmental Sciences, Bradford University, UK).

The fish remains were removed from the amphorae and stored for future study in cold seawater. Small samples of 0.12 g in total weight were extracted from the residue of each amphora base and studied under a microscope with a magnification of x10 (Figure 4). This small sample included a total of 3,251 fish remains (Table 1).

Taxonomic identification: Since the fish remains were very small, we enlarged the reference collection to include juvenile fish that were less than 10 cm in total length. The fish were collected from the research stations of the Department of Fisheries Ministry of Agriculture in Dor and

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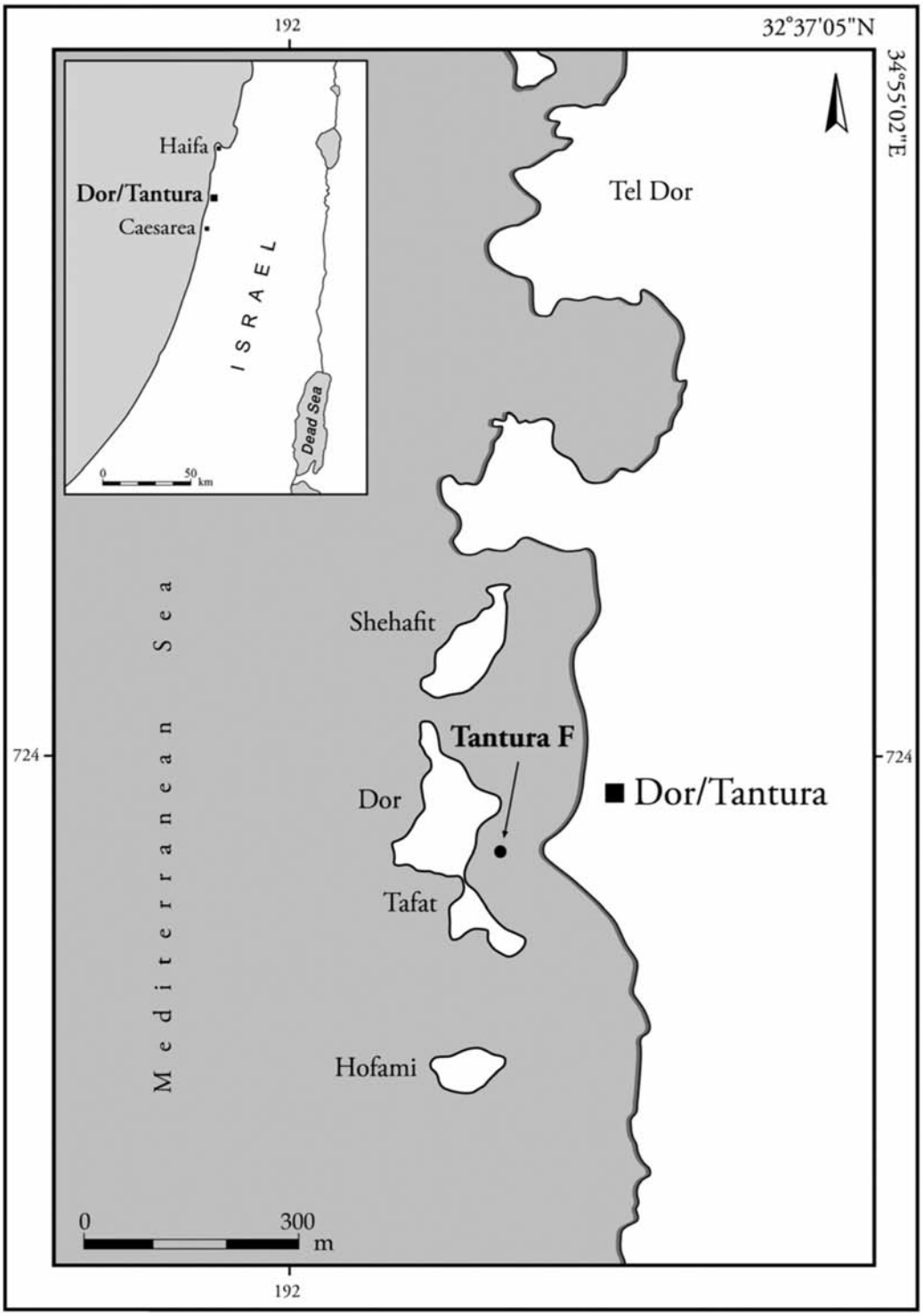

FIGURE 1
Tantura F location. (Drawing by S. Haad).

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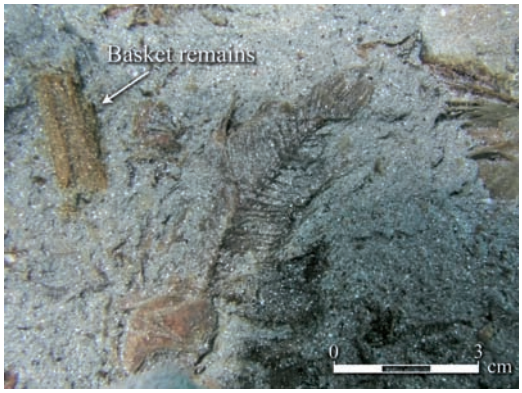

FIGURE 2

Skeletons of large fish exposed in the vicinity of a basket. (Photo by A. Yurman).

FIGURE 3

Ovoid amphora from the Tantura F. (Photo by J.J. Gottlieb).

Ginosar. These included juvenile fish belonging to Jordan St. Peter's fish (*Oreochromis aureus* Steindachner,1864) and Galilee St. Peter's fish (*Sarotherodon galilaeus* Linnaeus,1758).

FIGURE 4

Fish remains recovered from the Tantura F amphorae under x10 magnification. (Photo by J.J. Gottlieb).

Skeletal element identification: Tantura F fish remains were identified using Wheeler & Jones (1989) terminology and studies on cichlid systematics and morphological characteristics (Trewavas, 1983: 94-123; Stiassny, 1991: 1-35).

Body size estimation: For body size estimation (standard length), we collected 21 juvenile Jordan St. Peter's fish (*Oreochromis aureus* Steindachner,1864) with standard lengths ranging from 24 mm to 77 mm and 22 juvenile Galilee St. Peter's fish (*Sarotherodon galilaeus* Linnaeus,1758) with standard lengths of 30 mm to 96 mm.

Following Wheeler & Jones (1989) recommendation for body size estimation, we used three bones that were well preserved at Tantura F and that exhibited a high correlation with fish body size. These included the vomer from the olfactory region, the maxilla from the oromandibular region, and the cleithrum from the appendicular skeleton.

Using Morales & Rosenlund (1979), the following measurements were performed: for the vomer, the greatest oro-orbal length (Figure 5a, measurement #1) and the greatest medio-lateral breadth (Figure 5a, measurement #2); for the maxilla, the greatest length (Figure 5b, measurement #1) and the greatest height (Figure 5b, measurement #2); and for the cleithrum, we used the chord length (Figure 5c, measurement #2) and the height measured of a three contact point system (Figure 5c, measurement #1).

The regression equation calculated for each measurement appears in Table 2. As observed, all measurements were highly correlated with fish body size ($r>0.9$).

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	Sample no.								
Skeletal element	**4**	**8**	**16**	**29**	**31**	**33**	**44**	**57**	**Sum**
Neurocranium									
basioccipital	4	15	5	1	5	1	17	7	55
parasphenoid	4	6			15	30	6	6	67
postemporal	2	4	2	1	3	4		4	20
vomer	8	8	4	5	3	6	4	4	42
supraoccipital	3							4	7
skull bones	25	5	6	4	8	1	21	5	75
Branchiocranium									
articular	14	10		6	9	4	11	11	65
dentary	7	12		5	1	2	6	5	38
ectoptergoid	7	12	3	7		6	6	5	46
hyomandibular	2	5			8	6	4	7	32
interopercular		1		1	1			1	4
maxilla	25	5	16	7	8	6	21	5	93
opercular	11	15	12	14	15	4	30	23	124
pharygeal bone	6	6	5	7	4		11	10	49
premaxilla		4		4	1	2	1	4	16
preopercular	4	5	1	4	13			3	30
quadrate				1		4	1	1	7
subopercular	2	3	10	7	1	10	2	1	36
Appendicular skeleton									
pelvis		1		1	1	1		2	6
cleithrum		2		4			3		9
Vertebral column									
dorsal spine	45	35	25	60	92	120	11	80	468
first vertebra	11	8	9	16	10	10	8	8	80
interhaemal and anal spines	9	8	10	10	30	9	12	11	99
caudal vert?	5	4		15		6	9	9	48
vertebra	150	207	105	175	162	254	210	124	1387
Others									
scales	22	12	18	12	7	10	35	10	126
gill arches	5	15	120	25	10	17	22	8	222
Total	**371**	**408**	**351**	**392**	**407**	**513**	**451**	**358**	**3251**

TABLE 1

Skeletal elements identified in bones samples taken from eight 'bag shaped' amphorae in the Tantura F shipwreck.

RESULTS

Petrography and chemical analysis of the amphorae indicated that they were produced from Nile Delta silt (Barkai *et al*., 2010). This does not necessarily indicate the origin of the products they contained, because the amphorae may have been probably reused several times. Analysis of the residue in the amphorae by M. Kislev (Bar-Ilan University, Israel) identified the remains of a wheat weevil (*Sitophilus granarius*) (Figure 6), which is a wheat pest. This may indicate either

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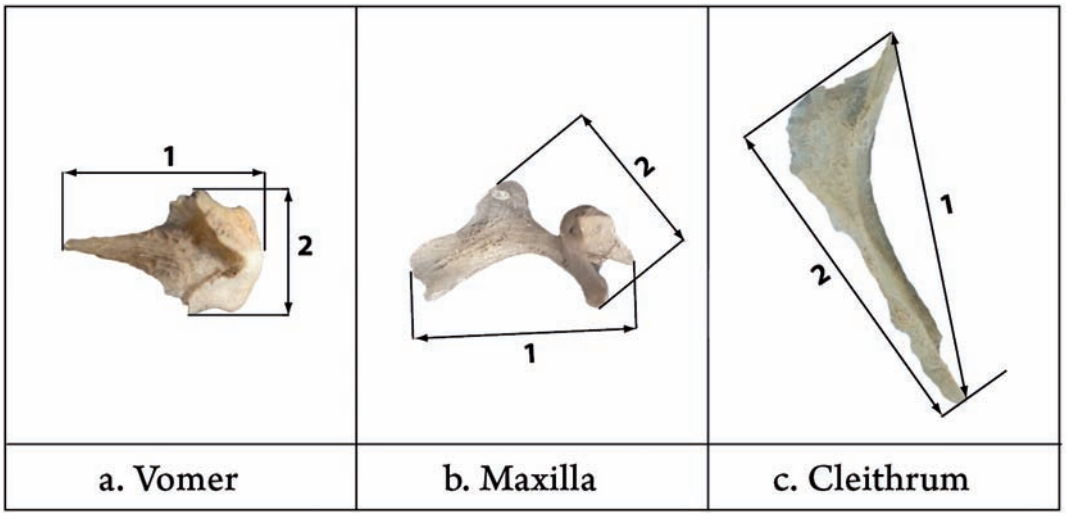

FIGURE 5

Measurements taken on cichlid bones for body size estimation: a) on the vomer; B) on the maxilla; C) on the cleithrum. (Photo by J.J. Gottlieb).

Bones measured	Regression equation for SL	n	p	r
Cleithrum 1	y=-9.884+4.111 X	21	0.0001	0.952
Cleithrum 2	y=-5.868+4.439 X	21	0.0001	0.952
Maxilla1	y=-5.175+12.461X	22	0.0001	0.97
Maxilla 2	y=-9.016+19.709 X	21	0.0001	0.936
Vomer 1	y=-2.558+10.902 X	22	0.0001	0.926
Vomer 2	y=-5.268+21.142 X	22	0.0001	0.968

TABLE 2

Regression equations for SL of small cichlids derived from measurements of bones of recent skeletonized fish (*Oreochro-mis aureus* and *Sarotherodon galilaeus*).

previous use of the same vessels for products other than fish, or infestation of pulses that had been added to the fish product (Van Neer *et al*., 2006).

The chemical analysis of the residue performed by Stern at the Department of Archaeological and Environmental Sciences, Bradford University, UK, was uninformative, probably due to the long immersion in seawater.

Fish remains in Tantura F amphorae

All of the eight amphorae contained a large assortment of fish skeletal elements, implying that complete fish were used. Interestingly, all of the 3,251 fish remains recovered from the Tantura F amphorae belonged to a single family, Cichlidae (Trewavas, 1983, Smits *et al*., 1996). From a taphonomical point of view, this result is important as Cichlidae are freshwater fish and therefore their appearance inside the amphora could have resulted only from human activity (Goren & Ortal, 1999: 1-9).

Taxonomic identification

Identification of cichlid remains to species level is not an easy task. The lower pharyngeal bone and

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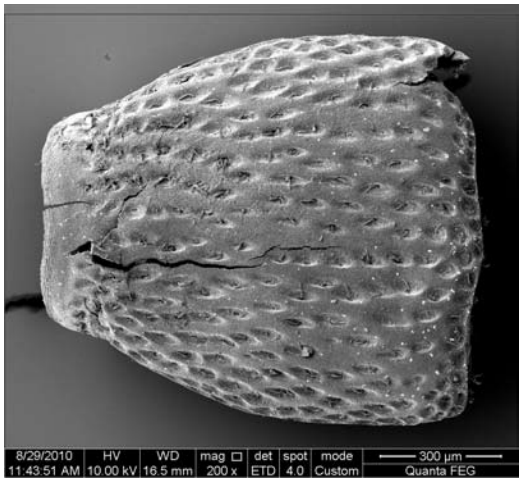

FIGURE 6

Remains of wheat weevil *Sitophilus granaries*, identified at Tantura F amphora (200x). (Photo by M. Kislev).

teeth are usually distinctive for each species (Malcolm, 2000; Radke *et al*., 2000: 961-967). In this study, however, we were unable to identify these fish remains to species level. This may be attributed to the very small size of the bones, their state of preservation, and the limited reference collection.

Body size estimation

Reconstruction of fish body size demonstrated that the original fish were between 17 to 40 mm SL (see Figure 5 and Table 2). The results show that, due to the small dimension of the bones, the measurement accuracy was very low (Table 3 and Figure 7).

DISCUSSION

Fish products were a popular source of food during the Roman period (Curtis, 2005: 31-46) and were traded (Studer, 1994: 191-196; Cotton *et al*., 1996: 228-238) and locally produced (Van Neer & Ervynck, 2004: 208-209; Van Neer *et al*. 2005: 171-182). Among the various forms of fish sauces used as condiments, salted fish (*salsamenta*) was the most common preparation.

Many industrial fish-product plants were established along the western Mediterranean and eastern Atlantic coasts of North Africa and the Iberian Peninsula. Archaeological excavations have uncovered the remains of large- and small fish-salting installations, dating from the 2nd century B.C.E. to the 7th century C.E. (Trakadas, 2004, 2005: 49-68, 2006). For example, over 60 fish-processing sites were recovered in Spain and Portugal alone (Curtis, 2009: 715s). Production and commerce in processed fish continued in the Byzantine period, but the scope of this practice varied greatly by geographical areas and over time (Curtis, 2005).

In the southern Levant, two fish-processing installations were identified from the Byzantine period: one in Gaza (Ovadiah, 1969: 193-198), and the other at Tel Taninnim (Everman, 2006: 59-87). The presence of fish-processing installations from the Byzantine period testifies that fish products were important and were traded to other settlements in the region. None of these installations, however, continued to function into the Islamic period. Toward the end of the 7th century C.E., with the Arab expansion along the eastern and southern coasts of the Mediterranean, the pattern of maritime trade changed entirely (Ashtor, 1970: 166-194; Cahen, 1980: 1-25; Laiou, 2002: 697-770). Little evidence addresses durability of trade directly, at any level between the Byzantine and Muslims in the 8th century. The constant state of war between the Arabs and the Byzantine Empire led to instability around the Mediterranean basin. This resulted in the destruction of Byzantine maritime commercial networks, followed by a decrease in the scope of economic activity in the Levant, including trade in fish products. The scale of manufacture of amphorae for commerce decreased, in both Byzantine and Muslim territories (Arthur, 1986; Walmsley, 2000: 327).

The processed fish facilities went out of use before the end of the 3rd century A.D. at other sites, particularly in parts of Tunisia. At Ceuta, Morocco, salting vats were utilized into the 5th or 7th centuries, but none of them continued to function in the 8th century (Curtis, 2005: 31-46; Trakadas, 2006)

Caesarea, which was one of the last cities to be conquered by Arab Muslims, retrained her role as an important port. «Bag-shaped» ovoid amphorae similar to those found in the Tantura F shipwreck were recovered at Caesarea (Arnon, 2008: 85-103; Raban & Yankelevitz, 2008). Although there is no clear indication of fish sauce production at this

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Measurement	Bone size	Estimated SL (mm)	Measurement	Bone size	Estimated SL (mm)
Vomer 1	2.50	25	Maxilla 1	2.55	27
Vomer 1	2.20	21	Maxilla 1	2.25	23
Vomer 1	3.70	38	Maxilla 1	2.36	24
Vomer 1	1.40	13	Maxilla 1	2.83	30
Vomer 1	2.26	22	Maxilla 1	2.67	28
Vomer 1	1.90	18	Maxilla 1	2.79	30
Vomer 1	1.37	12	Maxilla 1	3.37	37
Vomer 1	0.70	5	Maxilla 1	4.59	52
Vomer 1	2.10	20	Maxilla 1	2.03	20
Vomer 1	1.90	18	Maxilla 1	1.91	19
Vomer 2	1.70	31	Maxilla 2	1.24	15
Vomer 2	1.40	24	Maxilla 2	0.86	8
Vomer 2	2.24	42	Maxilla 2	1.60	23
Vomer 2	1.00	16	Maxilla 2	1.71	25
Vomer 2	1.46	26	Maxilla 2	1.74	25
Vomer 2	1.37	24	Maxilla 2	1.59	22
Vomer 2	0.96	15	Maxilla 2	2.32	37
Vomer 2	0.48	5	Maxilla 2	2.91	48
Vomer 2	1.40	24	Maxilla 2	1.50	21
Vomer 2	1.06	17	Maxilla 2	1.17	14
Cleithrum 1	9.73	30	Cleithrum 2	9.12	35
Cleithrum 1	11.10	36	Cleithrum 2	9.48	36
Cleithrum 1	8.21	24	Cleithrum 2	7.03	25
Cleithrum 1	8.43	25	Cleithrum 2	7.33	27
Cleithrum 1	9.22	28	Cleithrum 2	8.52	32
Cleithrum 1	7.70	22	Cleithrum 2	5.67	19
Cleithrum 1	7.84	22	Cleithrum 2	7.28	26

TABLE 3

Estimated body size (standard length in mm) of fish recovered from the amphorae.

industrial area, large concentrations of cichlid bones of medium-sized tilapia were found in an adjacent sewage canal dated to the Abbasid occupation level (750 C.E.) (Lernau, unpublished data). Therefore, it is possible that Caesarea replaced the industrial fish product along the western Mediterranean and eastern Atlantic coasts of North Africa and the Iberian Peninsula.

The fish remains recovered from the Tantura F amphorae provide clear evidence that, despite the decrease in long-distance commerce along the eastern Mediterranean coast during the early 8th century C.E., local trade continued to fulfill a major role in the economic life of this region (Lewis, 1951: 54-102; Hodges & Whitehouse, 1983: 56; McCormick, 2001: 573-604; von Grunebaum, 2008: 88). Tantura F cargo provides the sole evidence for fish sauce trade along the eastern Mediterranean coast during this dynamic period.

Fish sauces of the ancient world can be separated into two main types: the condiment *garum*, which was the clear fluid produced through a long process of fermentation of fish, and *allec*, the residue on the bottom of the production vessel (Curtis, 1984: 430-445; Lopetcharat *et al*., 2001; Grainger, 2007: 92-111). From a zooarchaeologi-

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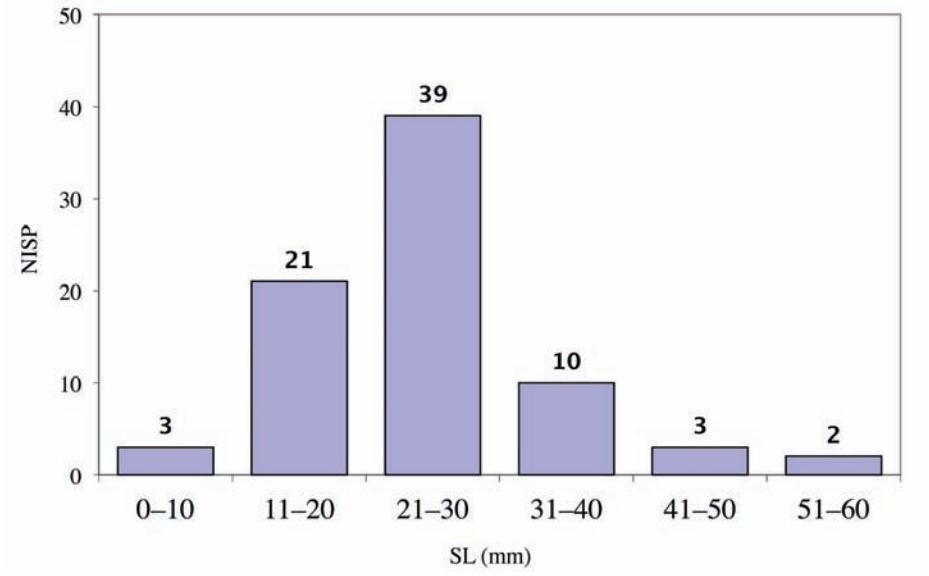

FIGURE 7
Estimated body size (standard length in mm) of cichlids recovered from Tantura F amphorae.

cal perspective, garum is *tituli picti* as it leaves no traces except for inscriptions. *Allec* is the sauce, however, that can be traced as it contained tiny bones of macerated fish.

Tantura F fish sauce is exceptional as it was made entirely out of tiny fish, 17-40 mm in total length; all of the remains belonged to cichlids which are freshwater fish, and skeletal elements from all parts of the skeleton were present. The producers of this sauce did not use small, leftover fish unfit for other purposes, as was described from other finds (Lepiksaar, 1986: 163-185). When several species of fish were used, the sauce was named *allec*. When larger and decapitated fish were used and kept in brine, the sauce was called *salsamenta* (Desse-Berset & Desse, 2000).

The exploitation of only one particular type of fish is probably an indication that this fish sauce was a product of high value. Fish sauces in the Roman world were usually prepared from marine fish, such as scombrids, sardines, and anchovies. In Egypt, however, there was also a long tradition of producing fish sauces and *salsamenta* from freshwater Nilotic fish (Van Neer & Depraetere, 2005).

It is suggested that the finds in the Tantura F shipwreck indicate a continuation of fish sauce production into the early Islamic period. Moreover, the preponderance of small cichlids may indicate fishing during the breeding season (spring-early summer) and perhaps a specialized fishing technology used for this purpose.

Identification of the origin of the fish sauce is not an easy task for several reasons: 1) scarcity of studies on fish production installation from the southern Levant; 2) as cichlids are widespread from Africa, it is nearly impossible to track their origin, unless endemic species occur in Israel, these include *Tristramella* (*T. sacra* and *T. simonis*) or *Astatotilapia flovijosephi*; and 3) only a few bones are species specific. In this case, however, due to the small size of the fish remains, identification to species level was impossible.

Our study demonstrated that the origin of the cichlid fish remains in the amphorae of the Tantura F shipwreck could not be identified, as their native distribution included various freshwater habitats from the Nile and along the Levant coast. Nevertheless, it may be suggested that the fish products carried in this ship were purchased from a local fish industry. Whether this was located in the adjacent site of Tel Dor or in Caesarea (13 km south) is still a mystery.

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CONCLUSIONS

The ovoid amphorae inside the hull remains of the Tantura F shipwreck probably contained a high-quality *allec* made of very small freshwater fish of the Cichlidae family. It was most likely not the only item on board, shipped between production sites and distant markets. The fish sauce could have originated in Egypt, where there was a long tradition of preparing *salsamenta* and sauces from freshwater fish. The shipwreck's close proximity to Caesarea, however, implies that the fish sauce may have been a result of local production. These findings and the shipwreck itself suggest that the lagoon and the settlement of Dor were on the commercial sailing routes during the early Islamic period.

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