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Fish and ancient lakes in the Dead Sea Rift: The use of fish remains to reconstruct the ichthyofauna of paleo-Lake Hula

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ABSTRACT

In this study we use fish remains recovered at the Acheulian site of Gesher Benot Ya'aqov, dated to 0.78 Ma, to reconstruct for the first time the fish community of paleo-Lake Hula. From Area A at the site, we identified 13 species belonging to three of the five recent native families of freshwater fish: Cyprinidae (carps), Cichlidae (Tilapinii, St. Peter fish), and Clariidae (catfish). The identified taxa included species endemic to Lake Hula, *Tristramella simonis intermedia* (Cichlidae) and *Mirogrex hulensis* (Cyprinidae), demonstrating continuity in the fish community for the last 0.8 million years. In addition, some of the species-specific bones exhibited different morphotypes that raise the possibility of the past existence of other endemic species of cyprinids and catfish in the lake, including the large molluskivores *Luciobarbus* sp. (formerly *Barbus*). The paleoenvironmental implications of the identified ichthyofauna for the complexity of the aquatic habitat of paleo-Lake Hula are discussed.

1. Introduction

Lake Hula, situated in the northern part of the Dead Sea Rift, Israel (Fig. 1), was a shallow lake with a long and dynamic geological history extending at least from the early Pleistocene (Horowitz, 1988, 2001). This history included periods of various hydrological connections, followed by hydrological isolations. Within this dynamic environment, the fish had to struggle to survive. Studies of the modern native fish community have shown that their ancestors have arrived through different migration routes from Africa and Eurasia (Goren and Ortal, 1999; Werner and Mokady, 2004). Consequently, the native fish community of Lake Hula exhibits both similarity to that of other freshwater habitats in the Dead Sea Rift Valley, Africa, and Eurasia, and speciation and evolution of several endemic species (Steinitz, 1953, 1959; Steinitz and Ben-Tuvia, 1960; Goren et al., 1973; Goren, 1974; Goren and Ortal, 1999; Zohar and Biton, 2011). The drainage of Lake Hula in the early 1950s (Dimentman et al., 1992) resulted in the extinction of the native and endemic fish community and the loss of the opportunity to study their evolution.

Although different approaches have been employed to assess environmental changes and speciation processes in paleo-Lake Hula and the Dead Sea Rift Valley (Feibel, 2004; Rosenfeld et al., 2004; Werner and Mokady, 2004; Por and Dimentman, 2006; van Zeist and Bottema, 2008; Spiro et al., 2009; Darling, 2011; Frumkin et al., 2011), these studies did not provide information on fish species composition in the paleo-lake. Since fish play a critical role in determining the structure, function, and stability of lake ecosystems (Bailey and Davidson, 1983), it is important to attempt to document evidence for major shifts in fish community structure and/or population size ("fish effect"). Studies of fish remains recovered in lacustrine sediments (bones, scales, and otoliths) have successfully shown their importance as markers for environmental changes (Soutar, 1966; Wilson, 1988; Wilson and Barton, 1996; Sakai et al., 2002; Whitefield and Elliot, 2002; Davidson et al., 2003; Drago et al., 2009; Reinthal et al., 2011). However, most of these studies were performed by core sampling in conditions that permitted the occurrence of well-preserved primary sedimentary structures with fish remains. These included regions associated with upwelling, high biological productivity, dense concentrations of small pelagic fishes, low oxygen concentrations of the overlying waters, and lack of bioturbation by benthic fauna.

Societies that depend on aquatic habitats will clearly be influenced by fluctuations in fish community structure. It is therefore important to identify and record such fluctuations. Such changes have never been recorded in the southern Levant, despite the fact that some archaeological sites are located in the vicinity of aquatic habitats (Van Neer et al., 2005). The present study is the first attempt to reconstruct the paleo-Lake Hula fish community 0.78 Ma. Specifically, we intend to ask:

1. Which fish remains (bones, scales, otoliths, teeth) are preserved in the lacustrine sediments of paleo-Lake Hula?

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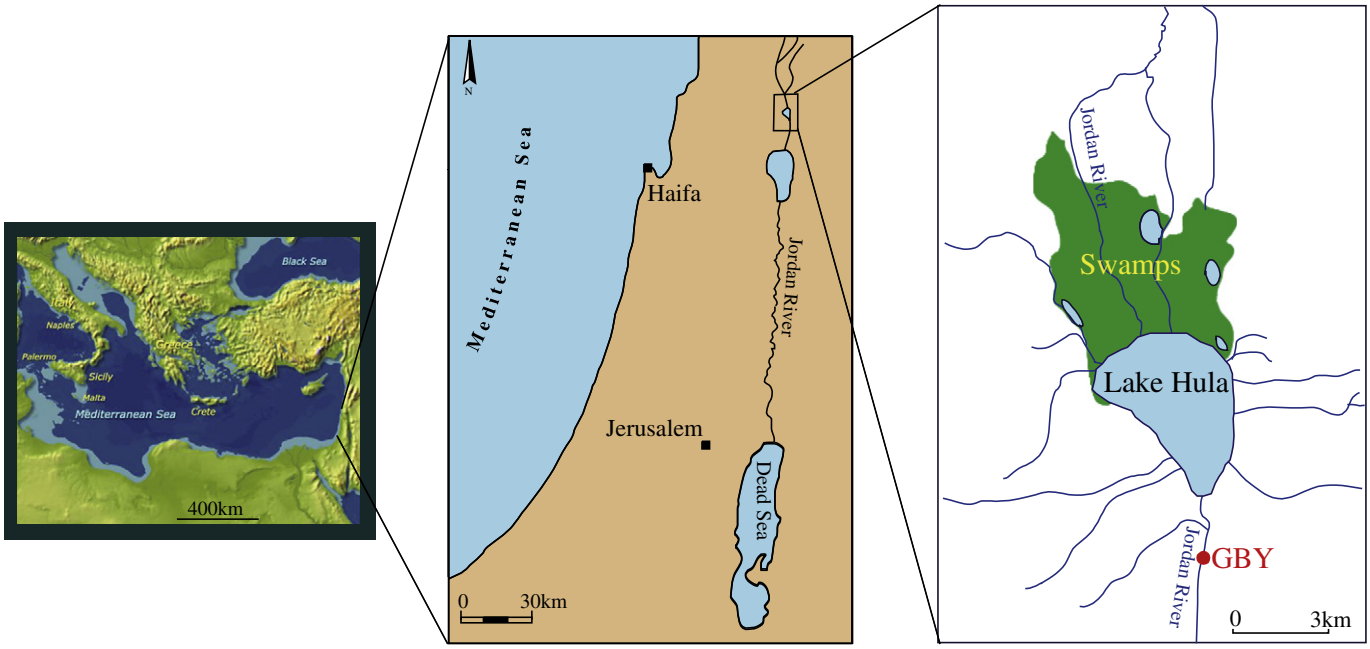

Fig. 1. Location map of Lake Hula before the 1950s drainage (modified after Dimentman et al., 1992) and the archaeological site of Gesher Benot Ya'aqov (Eastern Mediterranean map was modified from Destroyer History Foundation http://destroyerhistory.org/destroyers/maps/3do_mediterranean.html).

2. Which remains can be used for proper taxonomic identification?
3. To what extent do the remains reflect contemporary fish populations?
4. Which sampling method (core vs. archaeological excavations) better represents the fish community of paleo-Lake Hula?

2. Environmental and archaeological settings

Lake Hula is situated in the northern part of the Jordan Valley, the northernmost sector of the Dead Sea Rift (Dimentman et al., 1992; Horowitz, 2001; Belitzky, 2002). It was a pear-shaped lake that prior to its drainage in the 1950s was 5.5 km long and 4.4 km wide, with swamps north of the lake (Fig. 1).

Records exist from the 1930s for the water level and temperature of Lake Hula, showing that water level fluctuated between 1.5 and 4 m and water temperature ranged between 4 °C in the winter and 30 °C in the summer. Likewise, the total area of the lake and swamps fluctuated between 21 km^2 during the summer and 60 km^2 during the winter (Dimentman et al., 1992).

The Acheulian site of Gesher Benot Ya'aqov (GBY; Fig. 1) is located 3.5 km south of the Hula Valley, in the course and on both banks of the Jordan River (Goren-Inbar, 1992; Goren-Inbar et al., 2000; Belitzky, 2002). In the excavations at the site a well-documented 34 m thick sedimentary sequence was exposed, assigned to the Lower to Middle Pleistocene (MIS 18–20; Benot Ya'akov Formation); the estimated duration of the exposed sediments is in the order of 100 ka (Goren-Inbar et al., 2000; Feibel, 2001; Feibel, 2004). The sequence at GBY includes at least 45 discrete waterlogged sedimentary beds containing diverse floral and faunal remains and displaying evidence for hominin activity throughout the entire sequence, with 15 extremely rich archaeological horizons (Goren-Inbar, 1992; Goren-Inbar et al., 1992, 2000, 2001, 2004; Alperson-Afil et al., 2007; Rabinovich et al., 2008; Alperson-Afil et al., 2009; Alperson-Afil and Goren-Inbar, 2010; Goren-Inbar, 2011; Rabinovich et al., 2011). While the archaeological assemblages were deposited in lake-margin sediments that were quickly sealed and underwent minimal taphonomic processes, most of the lake sedimentary succession is fine-grained and contains mud of autochthonous origins (Feibel, 2004; Spiro et al., 2009). Hence, the fish remains embedded in the paleo-lake sediments provide a unique glimpse into the ancient fish community and its accessibility to early hominins about 0.78 Ma ago (Alperson-Afil et al., 2009; Zohar and Biton, 2011).

3. Material and methods

This study focuses on fish remains recovered at GBY from two different locations through two different sampling methods:

1. More than 10,000 fish remains recovered during the first season of archaeological excavation from Area A in the southern part of the site (Fig. 1). This is a relatively small area (5.25 m^2; 1.57 m^3) of tectonically tilted lacustrine sediments typical of fluctuating lake margins. The sediments vary between gray clay (Layer I-4) and coquina mixed with sandy and clayey lenses (Layer I-5). Although these layers include a few macroartifacts and many microartifacts smaller than 2 cm, they are less extensive and rich than archaeological horizons excavated in other areas of the site (Areas B and C) (Feibel, 2001; Goren-Inbar et al., 2004; Alperson-Afil et al., 2009). A previous study has showed that the fish remains found in the sediments of Area A represent a natural death community (Zohar et al., 2008; Zohar and Biton, 2011).
2. A small sample of fish remains obtained from 12 samples of a 50 m long core (GBY#2) drilled into the Benot Ya'akov Formation north of the archaeological site.

3.1. Fish identification

Fish remains were identified under a ZEISS stereomicroscope and a digital microscope (Dino-Lite Pro). Since the full composition of the past native ichthyofauna of paleo-Lake Hula is unknown and its modern community has become extinct, we utilized diverse reference collections of both modern and fossil fish to aid in identifying the fish remains. These collections included native fish fauna from Lake Hula (Table 1), Lake Kinneret, the Jordan River, and the coastal rivers of Israel (Zohar, 2003). We also used modern and fossil reference collections from the Levant and Africa housed at the Natural History Museums (NHM) of Brussels, Tervuren, London, and Paris (MNHN), as well as published ichthyological and paleontological data from a variety of different sources (Greenwood, 1972; Vandewalle, 1972; Banister, 1973; Greenwood,