DIVERSE OLIGOHALINE FORAMINIFERAL FAUNA AT ENOT TIMSAH, ISRAEL

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Abstract
The Enot Timsah spring system feeds an endangered wetland ecosystem at the foot of the Carmel Mountains. The site studied is isothermal, oligohaline (3-4 psu) and highly oligotrophic. Foraminiferal diversity consists of 15 live species and 3 more in the dead assemblage, reflecting a uniquely diverse marginal system. Richness is attributed to thermal stability, maturity dating to early Holocene, and position beneath bird migration routes. Low numbers, mainly of agglutinants, live in the top 4 cm. The dead assemblage is more numerous but records significant taphonomic loss of agglutinants and durability of hyalines; miliolid representation is unaffected.
Keywords: Biodiversity, Brackish Water, Eastern Mediterranean, Foraminifera

Introduction
The Enot Timsah nature reserve is located at the foot of the Carmel Mountains ~2.5 km from the Mediterranean. It constitutes the only significant natural outlet of the mountain aquifer system, and is the last remnant of the extensive Kebara wetlands, drained in the early 20th century. We here address the living foraminiferal assemblage that inhabited this ecosystem, as well as the dead assemblage that time-averages out patchiness and informs on taphonomic changes that allow comparison with the geologic record.

Material and Methods
The sampling station was located in an undisturbed spot in the Timsah reserve downstream from an active spring (32°33'9N/34°55'41E). Foraminifera were sampled monthly over one year in 2002-3. Temperature, conductivity, pH, major ion and nutrient concentrations of the water were determined. Sediments were taken using a 100 ml syringe to 4 cm depth. Living foraminifera were stained with Rose Bengal and preserved in 95% ethanol. Living and dead foraminifera >63µm were counted from 5 sets each from 8 sampling events.

Results and discussion
Enot Timsah is a unique ecosystem representing a ground/surface water interaction zone with very stable water properties. The system is nearly isothermal with temperature averaging 23.98±0.42 °C. It is oligohaline, with total dissolved solids (TDS) averaging 3,213.6±118.5 mg/l. pH averaged 7.05±0.15, in equilibrium with the carbonate aquifer source. PO_4^{3-} is the limiting nutrient in concentrations indicating oligotrophy. Organic carbon averaged 8.8±2.8 wt% with C/N ratio of ~14. Sediment is silty sand and % $CaCO_3$ is ~40%. Living foraminiferal abundance was 3 to 32 specimens/10 cc in the top 4 cm, much lower than in other oligohaline environments. Low numbers reflect the extremely low salinity, at the lower range for survival for most foraminifera, and the extreme oligotrophy, reflected by the high N/P, that limited phytoplankton production. 15 living and additional 3 dead species were recovered, comprising 8 agglutinants, 6 miliolids and 4 calcareous hyalines. This number of species is significantly higher than other environments of low salinity (Fig. 1). Occurrence of hyaline and miliolid taxa in oligohaline systems is atypical, and probably reflects the warm water and the high, stable Ca^{2+} and HCO_3^- concentrations contributed by the carbonate aquifer source. This wetland is located along the main migratory route of water fowl between Eurasia and Africa, so repetitive avian transport of cosmopolitan brackish foraminifera explains the high diversity. Also contributory is the long-term stability of temperature and salinity compared to marginal marine environments, as no significant change took place during the Holocene. Agglutinants comprise 49-80% of the living assemblage, hyalines 10-43%, and miliolids, 5-13%. The most common species are *Haplophragmoides manilaensis, H. wilberti* and *Trochammina inflata* that are low salinity indicators known from brackish environments. Others include *Birsteiniolla macrostoma* and *Pseudothurammina limneti*. Among miliolids, the shallow marine species *Affinitrina eburnea* is most common. Hyaline forms include *Cribroelphidium* cf. *C. vadescens* and *Trichohyalus aguayoi*. *Ammonia tepida* is present in small numbers. Noteworthy is relative abundance of *Bisaccium imbricatum*, a species recorded to date only from Louisiana. Foraminifera in the dead assemblage are more numerous. Hyalines are 2-6 times more abundant than in the living assemblage, while agglutinant numbers are sharply reduced. Among hyalines *A. tepida* abundance rises significantly. Miliolids comprise 5-13% of dead forms, similar to the living assemblage. The main control on taphonomic change is not the pH of 7.1, as calcareous miliolids and hyalines are more susceptible to dissolution than organic-cemented agglutinants. Selective preservation of calcareous tests is due mainly to the high HCO_3^- content and the $CaCO_3$-rich sediments, while decrease in agglutinants is due to extreme fragility of some tests, combined with microbial degradation of the organic cement.

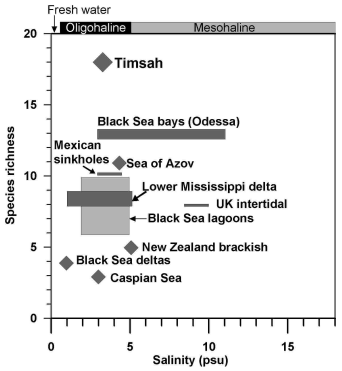

Fig. 1. Comparison of species richness in selected oligohaline (0.5-5 psu) and mesohaline (5-18 psu) settings. Values are high at Timsah, Black Sea, and Sea of Azov where salinity is more stable than in salt marshes and estuarine settings. Records were [1] for the lower Mississippi delta; [2] for the Black and Caspian seas and Sea of Azov; [3] for New Zealand brackish environments; [4] for UK intertidal zone; [5] for Mexican sinkholes

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