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The sub-Recent *Bradleytriebella lineata* (Ostracoda, Crustacea) in Israel

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ABSTRACT – Sub-Recent ostracod valves of *Bradleytriebella lineata* (Victor & Fernando, 1981) were recorded in Nahal Bokek only in 2008 but not during subsequent surveys in 2010 and 2013. Nahal Bokek, a stream entering the Dead Sea from its western escarpment, represents the species' single record in Israel, far away from its main Afrotropical and South to East Asia distribution. The temporary colonization of Nahal Bokek by *B. lineata* probably resulted from the suitability of the thermal stream waters for occupation and the subsequent termination of the population only six days after the collection of the sub-Recent valves during a flood on 24 October 2008. The preceding flood on 30 February 2008 restricts the period of possible stream inhabitation by *B. lineata* to a duration of eight months. Thus, the record of sub-Recent valves of *B. lineata* in Nahal Bokek represents an exceptional example of short-term occupation of a hydrologically dynamic flood-controlled water body by a species far away from its main geographical distribution. The recognition of Nahal Bokek as a stream fed mainly by thermal waters shows that the documentation of the abiotic habitat characteristics is a prerequisite for the understanding of the occurrence of a species outside its proper range of distribution.

KEYWORDS: *Ostracoda, thermal water, Dead Sea, Israel, Levant*

INTRODUCTION

Ostracods are important inhabitants of almost all types of water bodies. Their calcitic valves are often preserved in aquatic sediments and are therefore commonly used as palaeoenvironmental indicators in Quaternary geology and in palaeoclimate reconstructions (De Deckker & Forester, 1988; Boomer *et al.*, 2003; Frenzel & Boomer, 2005). Knowledge of the distribution of modern ostracods is a prerequisite for its use as a tool in palaeoenvironmental studies (Mezquita *et al.*, 2005; Reed *et al.*, 2012). A recent survey of the distribution of modern non-marine ostracods in southern Israel and Jordan showed that the species *Bradleytriebella lineata* (younger synonym *Paracypretta amati* Martens, 1984) occurs only at one of the 34 sites examined in Israel (Mischke *et al.*, 2012). It was not recorded in an earlier 61-site survey by Mischke *et al.* (2010) and in other studies of non-marine Recent or sub-Recent ostracods from Israel (Lerner-Seggev, 1968; Rosenfeld & Ortal, 1983; Martens *et al.*, 1992, 2002; Martens & Ortal, 1999). The objective of this study is the determination of the distribution of *B. lineata* in the region of its single discovery in Israel and the discussion of possible reasons for its rare occurrence in the southern Levant.

STUDY AREA

Valves of *B. lineata* have been recorded from a single sampling site in Nahal Bokek (= the Bokek stream, also Wadi Boqeq) in Israel so far (Mischke *et al.*, 2012). Nahal Bokek is a relatively small stream that drains the western rift shoulder of the Dead Sea basin (Fig. 1). The rift shoulder forms a steep cliff between the uplands of the Judean Desert with elevations generally above sea-level (asl) and the Dead Sea at −427 m asl. The stream of Nahal Bokek is deeply incised in Upper Cretaceous carbonates and mudstones (Wdowinski & Zilberman, 1997).

The climate of the region is hyperarid, with mean annual precipitation of 75 mm. Mean annual, mean January and mean July temperatures are 24.1 °C, 15.3 °C and 31.2 °C, respectively. As a result of the arid conditions, vegetation is confined mostly to the narrow gorge of Nahal Bokek, consisting of *Tamarix, Phragmites* and salt-tolerant Chenopodiaceae. The stream flows west–east over a distance of *c*. 1.8 km and enters the Dead Sea at the tourist resort Ein Bokek (also En Boqeq; Fig. 1). The proximity of a number of large hotels and of the major road number 90 which crosses the stream close to its inflow into the Dead Sea results in its attraction as an important hiking destination. Thus, human impact occurs mostly through tourists wading in the stream bed and leaving litter in the stream and on nearby tracks.

MATERIAL AND METHODS

In addition to two sites previously sampled during 2008 and 2010, nine sites were sampled along the stream in December 2013 (Fig. 1). The uppermost 0.5 cm-thick soft mud was collected from slowly flowing sections in the stream, small pool-like basins in the stream bed or calm areas behind large rocks. If present at all, only a thin (<2 cm) cover of soft sub-Recent sediments drapes gravels and rocks in Nahal Bokek. These soft and fine-grained sediments apparently represent deposition since the last local flooding event which flushed out previously accumulated fine-grained sediments from the stream bed. At each site, 130 ml of soft wet sediment were collected. Specific conductivity, water temperature, dissolved oxygen concentration and saturation, and pH were measured at each site with a hand-held WTW 340i device. A single water sample was collected at Site 7 in 2013 for subsequent analyses of major cations and anions and alkalinity was immediately determined with the AL7 titration test kit of Macherey-Nagel. The sediment samples were sieved through 1, 0.25 and 0.1 mm meshes on the day of sampling. The sieve residues were stored in water for 11 days and dried. Ostracod valves and carapaces were subsequently picked using a low-power binocular microscope. Ostracod valves were identified with Rossetti *et al.* (2006) and Savatenalinton & Martens (2010).

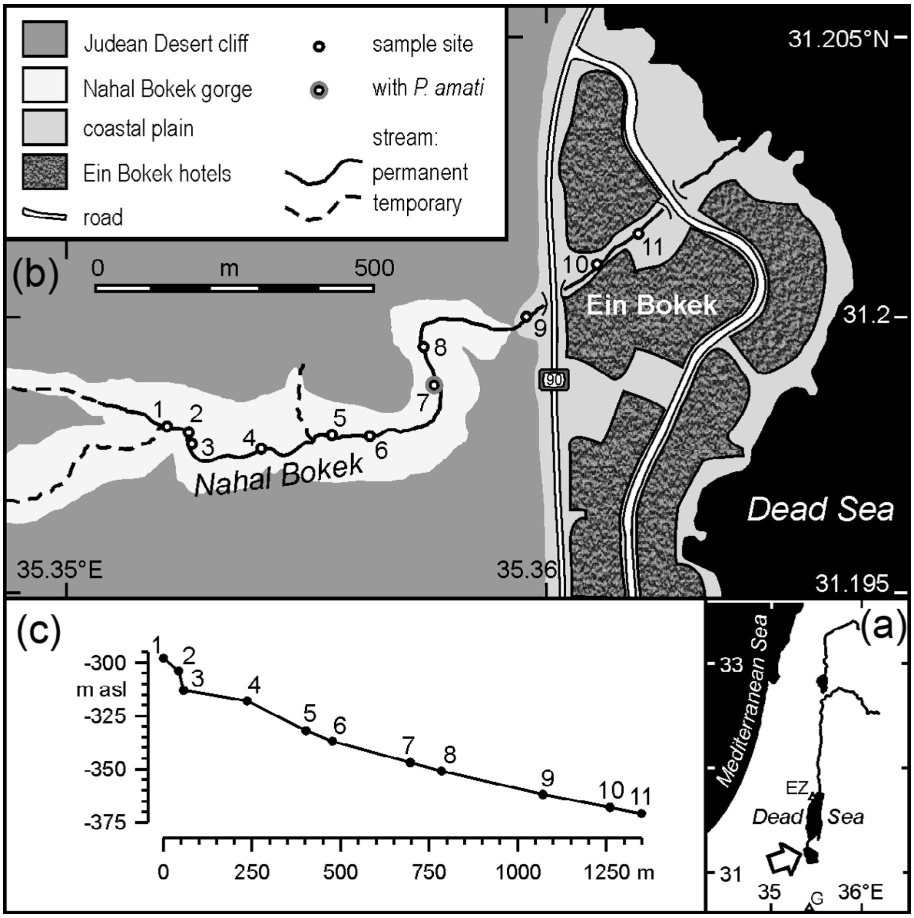

Fig. 1. Nahal Bokek at the western shore of the Dead Sea in Israel: (**a**) general position of study area marked with an arrow (EZ, Enot Zuqim; G, Gharandal); (**b**) sampled sites in Nahal Bokek; (**c**) altitudinal transect with sampled sites along Nahal Bokek.

RESULTS

The specific conductivity of Nahal Bokek is relatively high and increases slightly downstream from 11.42 mS cm^{-1} at the uppermost Site 1 to 11.92 mS cm^{-1} at Site 11 close to its inflow into the Dead Sea (Fig. 2). Water temperatures decrease from 29.6 °C to 21.6 °C over the same distance. The pH values show a slight increase, and also dissolved oxygen concentration increases slightly downstream apart from the lowermost site where a high oxygen concentration was measured (Fig. 2). The major anion and cation concentration of Nahal Bokek water is dominated by Cl^-, and Mg^{2+} and Ca^{2+}, respectively (Fig. 3). Water samples collected during different years do not show a significant variability in major ion proportions. Ostracod valves were not found at the two uppermost Sites 1 and 2 in Nahal Bokek and also not at Sites 4 and 9 (Fig. 2). Valves of *Heterocypris salina* (Brady, 1868) were found at the other seven sites sampled in 2013 (Fig. 4). Two carapaces of *H. salina* with well-preserved soft parts were recorded at Site 10. Valves of *B. lineata* were found only at Site 8 in October 2008.

DISCUSSION

The Nahal Bokek water has a significantly higher conductivity and water temperature than the freshwater springs of En David and Nahal Arugot at the western shore of the northern Dead Sea basin (Vengosh *et al.*, 1991). The water temperature of Nahal Bokek decreases downstream (Fig. 2). The temperature is *c.* 6 °C higher in its uppermost stream section in comparison to the mean annual temperature of Ein Bokek (Fig. 2). The higher water temperature and conductivity in comparison to the freshwater springs of the region, and the downstream-temperature decrease indicate that Nahal Bokek is apparently mostly fed by a thermal spring or several thermal springs. Such springs are common features along the Dead Sea Transform (Mazor & Molcho, 1972; Salameh & Rimawi, 1984; Vengosh *et al.*, 1991). In addition to thermal spring water, recent meteoric water probably contributes to the stream water of Nahal Bokek. The Cl^- dominance of Nahal Bokek and Dead Sea waters indicates that the stream waters are influenced by deep buried ancient sea water from the initial lagoonal stage of the Dead Sea basin or more recent Dead Sea brines (Mazor & Molcho, 1972) (Fig. 3). However, the differences in the major cation proportions of the waters from Nahal Bokek, the Dead Sea surface brine and the deep thermal spring waters from Enot Zuqim (also known as Enot Tsukim or En Feshra) at the northwestern shore of the Dead Sea show that the Nahal Bokek waters do not represent exclusively deep saline waters similar to most spring waters of Enot Zukim or mixtures of uprising waters and the recent Dead Sea brine (Mazor & Molcho, 1972) (Fig. 1). The Ca^{2+} dominance of the Nahal Bokek waters probably results

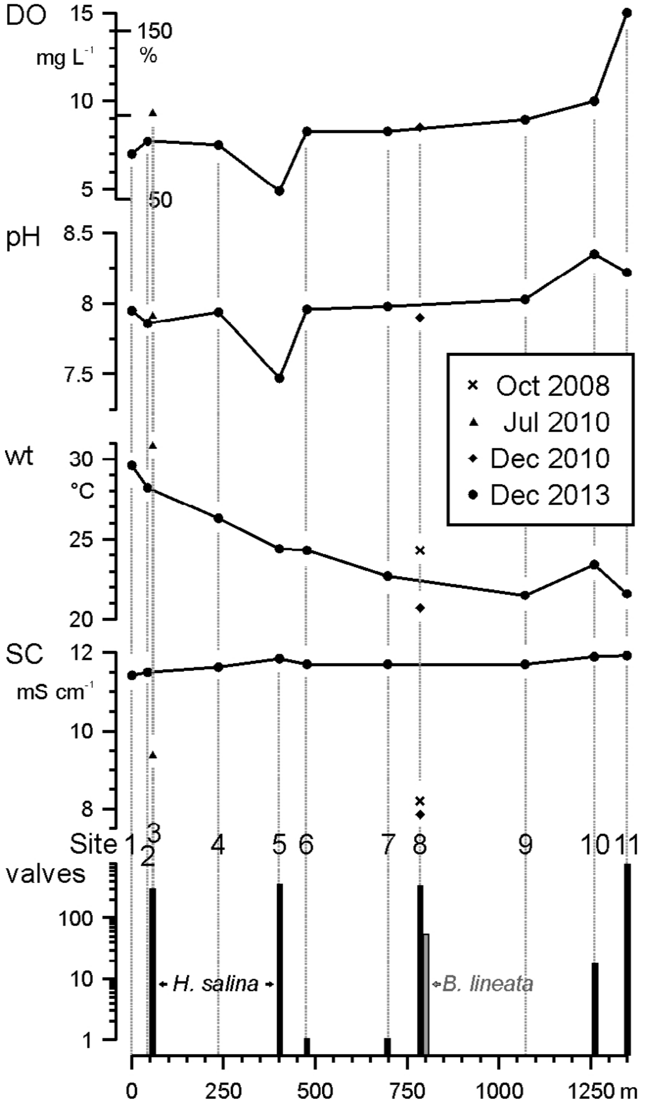

Fig. 2. Dissolved oxygen (DO) concentration (mg l^{-1}) and saturation (%), water temperature (wt), pH, specific conductivity (SC) and numbers of recorded valves of *Heterocypris salina* and *Bradleytriebella lineata* at the eleven sampled sites in Nahal Bokek. (Sampling time of previous studies and this survey marked with different symbols.)

from the admixture of recent meteoric waters with waters of deep origin (Fig. 3).

The pH value of Nahal Bokek waters slightly increases downstream, probably as a result of increasing CO_2 degassing along the water's flow. The slight conductivity increase measured downstream in 2013 probably reflects the increasing evaporative concentration of the water with increasing time of exposure (Fig. 2). Dissolved oxygen concentration and saturation increase downstream as a result of increasing uptake of atmospheric oxygen in turbulent waters and increasing algal productivity in less rapidly flowing waters downstream.

Conductivities of Nahal Bokek waters were significantly lower at Site 8 in the years 2008 and 2010 in comparison to the conductivity at the nearby Site 7 in 2013 (Fig. 2). A reason for the recent conductivity increase is possibly the increasing aridity of the region and the diminishing dilution of thermal and saline spring water by near-surface fresh groundwater (Ziv *et al.*, 2013).

Valves of *B. lineata* were recorded at Site 8 only during the sampling survey in October 2008 in Nahal Bokek (Fig. 2). The sampling of Site 3 in July 2010 and Site 8 in December 2010, and the more systematic sampling of sediments along the stream in 2013 revealed only valves and carapaces of *H. salina.* Specimens of *H. salina* collected alive at Site 10 in December 2013 show that the species lived in the stream during the most recent sampling survey. The widely distributed and ecologically tolerant species *H. salina* apparently represents the established, long-term inhabitant of the brackish Nahal Bokek waters. In contrast, *Bradleytriebella lineata* seems to occur only sporadically. The species has been recorded from its type locality comprising ponds, roadside ditches, a lake and a washing pool in the Philippines, from temporary ponds in a temporary river from Sudan, from lakes, reservoirs, streams, canals, ponds, swamps, rice fields and springs in Thailand, from the freshwater Lake Biwa in Japan, and spring-fed ponds in Wadi Gharandal in southern Jordan (Victor & Fernando, 1981; Martens, 1984; Savatenalinton & Martens, 2010; Smith *et al.*, 2011; Mischke *et al.*, 2012). Apart from the records in Nahal Bokek and Wadi Gharandal, it was not recorded from any other site in the region in a number of studies of Recent to Quaternary ostracods (Bender, 1968; Huckriede & Wiesemann, 1968; Almogi-Labin *et al.*, 1995; Ginat *et al.*, 2003; Moumani *et al.*, 2003; Petit-Maire *et al.*, 2010; Mischke *et al.*, 2012). Thus, *B. lineata* has apparently an

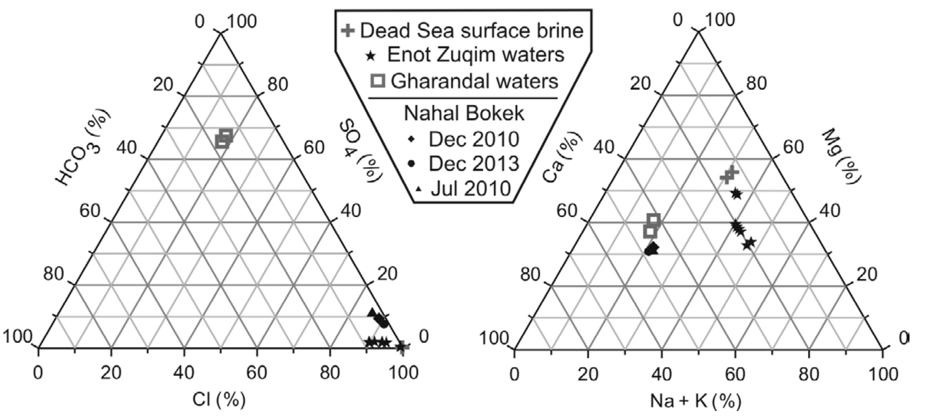

Fig. 3. Major cations and anions of Nahal Bokek water sampled in July and December 2010 and in December 2013 (Mischke *et al.*, 2012). Ion concentration data for the Dead Sea surface brine, waters of the Enot Zuqim springs at the northwestern Dead Sea shore, and spring and pond waters of Wadi Gharandal in Jordan are given for comparison (Mazor & Molcho, 1972; Abed *et al.*, 1990; Mischke *et al.*, 2012). In addition to the occurrence of *B. lineata* in Nahal Bokek in Israel, another record of valves of *B. lineata* from the Levant comes only from a spring and a pond in Wadi Gharandal in Jordan (Mischke *et al.*, 2012).

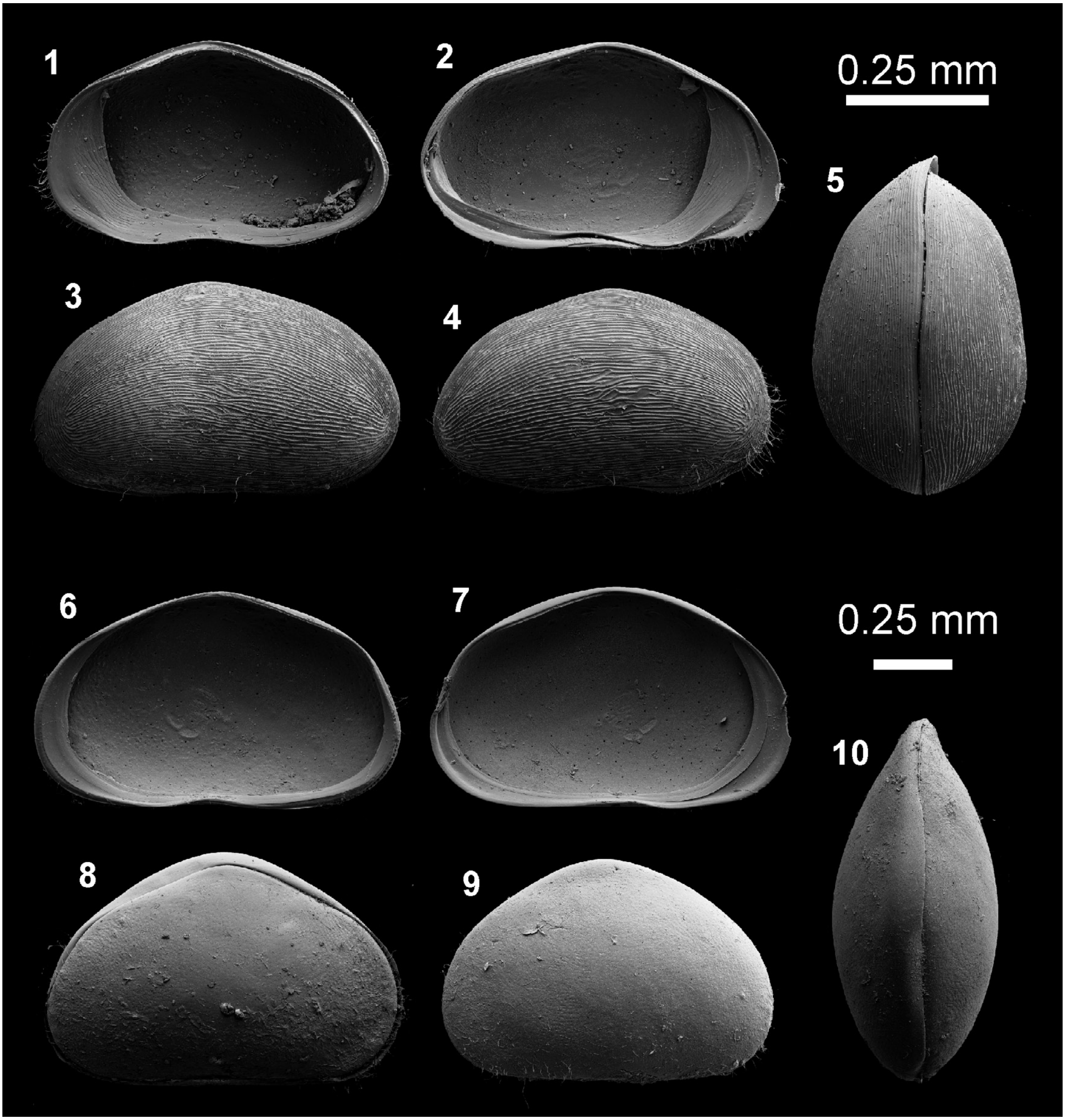

Fig. 4. *Bradleytriebella lineata* (1–5) and *Heterocypris salina* (6–10) from Nahal Bokek: **1**, right valve (RV) internal view (iv); **2**, left valve (LV) iv; **3**, LV external view (ev); **4**, RV ev; **5**, carapace (C) dorsal view (dv); **6**, RV iv; **7**, LV iv; **8**, C ev (RV visible); **9**, C ev (LV visible); **10**, C dv. All specimens housed at the Institute of Geological Sciences of the Freie Universität Berlin.

Afrotropical, Oriental and East Asian distribution (Savatenalinton & Martens, 2011; Smith *et al.*, 2011).

Ecological information for the type locality of *B. lineata* in the Philippines and the record from Sudan is lacking but a pH range from 6.5 to 7.2 and a water temperature range from 23.4 °C to 34.5 °C is reported from the records in Thailand (Victor & Fernando, 1981; Martens, 1984; Savatenalinton & Martens, 2010). Summer temperatures of Lake Biwa's surface waters are *c*. 29 °C (Endoh, 1978). Significantly lower water temperatures between 14.9 and 22.2 °C and pH values between 7.2 and 8.1 were measured in Wadi Gharandal (Mischke *et al.*, 2012). However, only empty carapaces and valves were recorded at the Jordanian locality. The temperature data measured in Wadi Gharandal during sampling in December 2010 probably represent minimum temperatures for the full year's cycle. The predominantly tropical distribution of *B. lineata* and the reported water temperature data for the localities in Thailand, Japan and for Nahal Bokek indicate that *B. lineata* prefers warm waters (Savatenalinton & Martens, 2010, 2011). Specific conductivities of 1.9–2.3 $mS\,cm^{-1}$ in the ponds of Wadi Gharandal and freshwater conditions of the localities of *B. lineata* in Thailand (K. Martens, pers. comm., 2014) and Japan (Aota *et al.*, 2003) suggest that the species tolerates a relatively wide salinity range. The species has apparently no preference for waters dominated by either Cl^- or SO_4^{2-} and possibly a preference for waters rich in Ca^{2+} and Mg^{2+} (Fig. 3).

The record of *B. lineata* from the thermal waters of Nahal Bokek in 2008 represents an occasional and temporary appearance in an ecologically suitable habitat far away from the usual region of the species' distribution. It remains open whether the occurrence in Nahal Bokek resulted from the dispersal of eggs and/or living specimens by birds migrating along the major north–south-aligned African Rift Valley–Red Sea route connecting eastern Africa and Eurasia (Bobek *et al.*, 2008).

The disappearance of the population after the sampling of sub-Recent valves on 18 October 2008 was probably caused by a flood recorded in Nahal Bokek only six days after sampling on 24 October 2008 (Hydrological Service of Israel, unpubl. data). A preceding flood occurred in the region on 30 February 2008, leaving a period of about eight months of calm and probably suitable conditions for the establishment of a *B. lineata* population in Nahal Bokek (Hydrological Service of Israel, unpubl. data). The absence of sub-Recent valves from the stream in December 2013 indicates that the species was apparently not able to efficiently re-occupy Nahal Bokek.

CONCLUSIONS

Sub-Recent valves of *B. lineata* were recorded at only a single site in Nahal Bokek in an earlier study and were not recovered in a more systematic sampling of the stream in 2013. Its absence is explained by the flushing of the stream bed during a flood on 24 October 2008 only six days after the sampling of sub-Recent valves and the inability of the species to re-establish a population in the stream. The study shows that the short-term occupation of water bodies such as Nahal Bokek by a species far away from its main distribution region is controlled by (1) the site-specific suitability of the habitat for occupation (i.e. the thermal waters of Nahal Bokek) and (2) the specific hydrological conditions (flooding in Nahal Bokek). Only frequent and systematic surveys are capable of tracing the occupation dynamics of similar short-lived occurrences of ostracods and probably also other taxa in flood-affected waters of arid regions.

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REFERENCES

Abed, A., Al-Sbaeay, I. & Khbeis, S. 1990. The Dead Sea: A recent survey of its waters. *Proceedings of the 3rd Jordanian Geological Conference*, Annan, 3–5 April 1988, 446–472.

Almogi-Labin, A., Siman-Tov, R., Rosenfeld, A. & Debard, E. 1995. Occurrence and distribution of the foraminifer *Ammonia beccarii tepida* (Cushman) in water bodies, Recent and Quaternary, of the Dead Sea Rift, Israel. *Marine Micropaleontology*, **26**: 153–159.

Aota, Y., Kumagai, M. & Ishikawa, K. 2003. Over twenty years trend of chloride ion concentration in Lake Biwa. *Journal of Limnology*, **62**: 42–48.

Bender, F. 1968. *Geologie von Jordanien. Beiträge zur Regionalen Geologie der Erde, 7*. Gebrüder Borntraeger, Stuttgart, 230pp.

Bobek, M., Hampl, R., Peške, L., Pojer, F., Šimek, J. & Bureš, S. 2008. African Odyssey project – satellite tracking of black storks *Ciconia nigra* breeding at a migratory divide. *Journal of Avian Biology*, **39**: 500–506.

Boomer, I., Horne, D.J. & Slipper, I.J. 2003. The use of ostracods in palaeoenvironmental studies, or what can you do with an ostracod shell? *In* Park, L.E. & Smith, A.J. (Eds), *Bridging the gap: Trends in the ostracode biological and geological sciences*. The Paleontological Society Special Publications, Paleontological Society Papers, New Haven, 153–179.

De Deckker, P. & Forester, R.M. 1988. The use of ostracods to reconstruct continental palaeoenvironmental records. *In* De Deckker, P., Colin, J.-P. & Peypouquet, J.-P. (Eds), *Ostracoda in the earth sciences*. Elsevier, Amsterdam, 175–199.

Endoh, S. 1978. Diagnostic analysis of water circulations in Lake Biwa. *Journal of the Oceanographical Society of Japan*, **34**: 250–260.

Frenzel, P. & Boomer, I. 2005. The use of ostracods from marginal marine, brackish waters as bioindicators of modern and Quaternary environmental change. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **225**: 68–92.

Ginat, H., Zilberman, E. & Saragusti, I. 2003. Early Pleistocene lake deposits and Lower Paleolithic finds in Nahal (wadi) Zihor, Southern Negev desert, Israel. *Quaternary Research*, **59**: 445–458.

Huckriede, R. & Wiesemann, G. 1968. Der jungpleistozäne Pluvial-See von El-Jafr und weitere Daten zum Quartär Jordaniens. *Geologica et Paleontologica*, **2**: 73–95.

Lerner-Seggev, R. 1968. The fauna of Ostracoda in Lake Tiberias. *Israel Journal of Zoology*, **17**: 117–143.

Martens, K. 1984. On the freshwater ostracods (Crustacea, Ostracoda) of the Sudan, with special reference to the Red Sea Hills, including a description of a new species. *Hydrobiologia*, **110**: 137–161.

Martens, K. & Ortal, R. 1999. Diversity and zoogeography of inland-water Ostracoda (Crustacea) in Israel (Levant). *Israel Journal of Zoology*, **45**: 159–173.

Martens, K., Ortal, R. & Meisch, C. 1992. The ostracod fauna of Mamilla Pool (Jerusalem, Israel) (Crustacea, Ostracoda). *Zoology in the Middle East*, **7**: 95–114.

Martens, K., Schwartz, S.S., Meisch, C. & Blaustein, L. 2002. Non-marine Ostracoda (Crustacea) of Mount Carmel (Israel), with taxonomic notes on Eucypridinae and circum-mediterranean *Heterocypris*. *Israel Journal of Zoology*, **48**: 53–70.

Mazor, E. & Molcho, M. 1972. Geochemical studies on the Feshcha Springs, Dead Sea basin. *Journal of Hydrology*, **15**: 37–48.

Mezquita, F., Roca, J.R., Reed, J.M. & Wansard, G. 2005. Quantifying species–environment relationships in non-marine Ostracoda for ecological and palaeoecological studies: Examples using Iberian data. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **225**: 93–117.

Mischke, S., Almogi-Labin, A., Ortal, R., Rosenfeld, A., Schwab, M.J. & Boomer, I. 2010. Quantitative reconstruction of lake conductivity in the Quaternary of the Near East (Israel) using ostracods. *Journal of Paleolimnology*, **43**: 667–688.

Mischke, S., Ginat, H., Al-Saqarat, B. & Almogi-Labin, A. 2012. Ostracods from water bodies in hyperarid Israel and Jordan as habitat and water chemistry indicators. *Ecological Indicators*, **14**: 87–99.

Moumani, K., Alexander, J. & Bateman, M.D. 2003. Sedimentology of the late Quaternary Wadi Hasa Marl Formation of central Jordan: A record of climate variability. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **191**: 221–242.

Petit-Maire, N., Carbonel, P., Reyss, J.L. *et al*. 2010. A vast Eemian palaeolake in southern Jordan (29°N). *Global and Planetary Change*, **72**: 368–373.

Reed, J.M., Mezquita-Joanes, F. & Griffiths, H.I. 2012. Multi-indicator conductivity transfer functions for Quaternary palaeoclimate reconstruction. *Journal of Paleolimnology*, **47**: 251–275.

Rosenfeld, A. & Ortal, R. 1983. Ostracods as indicators of water pollution in Nahel Harod, northern Israel. *In* Maddocks, R.F. (Ed.), *Applications of Ostracoda*. University of Houston Geosciences, 229–237.

Rossetti, G., Martens, K., Meisch, C., Tavernelli, S. & Pieri, V. 2006. Small is beautiful: Diversity of freshwater ostracods (Crustacea, Ostracoda) in marginal habitats of the province of Parma (Northern Italy). *Journal of Limnology*, **65**: 121–131.

Salameh, E. & Rimawi, O. 1984. Isotopic analysis and hydrochemistry of the thermal springs along the eastern side of the Jordan–Dead Sea–Wadi Araba Rift Valley. *Journal of Hydrology*, **73**: 129–145.

Savatenalinton, S. & Martens, K. 2010. On the subfamily Cypricercinae McKenzie, 1971 (Crustacea, Ostracoda) from Thailand, with the description of six new species. *Zootaxa*, **2379**: 1–77.

Savatenalinton, S. & Martens, K. 2011. A subjective checklist of the Recent, free-living, non-marine Ostracoda (Crustacea). *Zootaxa*, **2855**: 1–79.

Smith, R.J., Janz, H. & Okubo, I. 2011. Recent Cyprididae and Ilyocyprididae (Crustacea: Ostracoda) from Lake Biwa, Japan, including a summary of the lake's ostracod fauna. *Zootaxa*, **2874**: 1–37.

Vengosh, A., Starinsky, A., Kolodny, Y. & Chivas, A.R. 1991. Boron isotope geochemistry as a tracer for the evolution of brines and associated hot springs from the Dead Sea, Israel. *Geochimica et Cosmochimica Acta*, **55**: 1689–1695.

Victor, R. & Fernando, C.H. 1981. Freshwater Ostracods (Crustacea: Ostracoda) of the genus *Strandesia* Vavra, 1895 from Malaysia, Indonesia and the Philippines. *Archiv für Hydrobiologie*, Suppl. **58**: 469–522.

Wdowinski, S. & Zilberman, E. 1997. Systematic analyses of the large-scale topography and structure across the Dead Sea Rift. *Tectonics*, **16**: 409–442.

Ziv, B., Saaroni, H., Pargament, R., Harpaz, T. & Alpert, P. 2013. Trends in rainfall regime over Israel, 1975–2010, and their relationship to large-scale variability. *Regional Environmental Change*, http://dx.doi.org/10.1007/s10113-013-0414-x