Check List the journal of biodiversity data

NOTES ON GEOGRAPHIC DISTRIBUTION

Check List 14 (5): 811–815
https://doi.org/10.15560/14.5.811

PENSOFT

Occurrence of *Keratella cochlearis* (Gosse, 1851) (Rotifera, Monogononta) on San Cristóbal Island, Galápagos Archipelago, Ecuador

Carlos López[1,2], Miriam Steinitz-Kannan[3], Hendrik Segers[4]

1 Escuela Superior Politécnica del Litoral, ESPOL, Facultad de Ciencias de la Vida y Centro del Agua y Desarrollo Sustentable, Campus Gustavo Galindo, Km 30.5 Vía Perimetral, Guayaquil 090903, Ecuador. **2** Departamento de Biología. Facultad Experimental de Ciencias. Universidad del Zulia, Maracaibo 4011-A, Venezuela. **3** Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099, USA. **4** Operational Directorate Natural Environment, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium.
Corresponding Author: Carlos López, cllopez@espol.edu.ec

Abstract
The presence of the rotifer *Keratella cochlearis* (Gosse, 1851) is reported in El Junco Lake, a freshwater crater lake in San Cristóbal Island, Galápagos Islands. This taxon is a known species aggregate containing both eurytopic cosmopolitans as well as local and regional endemics, but also some insufficiently documented cryptic species. This record is the first of a representative of the aggregate for the rotifer fauna of the Galápagos Islands. Considering that the animal is now being recorded from the lake while earlier surveys did not, and the high dispersal capacity of many rotifers, we hypothesize that the organism recorded is one of the more widespread members of the aggregate, which colonized El Junco Lake only recently.

Key words
Distribution; micrometazoa; Neotropics; oceanic islands; South America.

Academic editor: Sergio N. Stampar | Received 23 May 2018 | Accepted 14 September 2018 Published 5 October 2018

Citation: López C, Steinitz-Kannan M, Segers H (2018) Occurrence of *Keratella cochlearis* (Gosse, 1851) (Rotifera, Monogononta) on San Cristóbal Island, Galápagos Archipelago, Ecuador. Check List 14 (5): 811–815. https://doi.org/10.15560/14.5.811

Introduction

Because of their origin, isolation and history of scientific exploration, the Galápagos Islands, oceanic territories of Ecuador, remain of extraordinary interest for biogeographical studies (Segers and Dumont 1993). Notwithstanding this there are few contributions on the freshwater fauna of the archipelago, and this also holds for the Rotifera as representative taxon of aquatic micrometazoan. De Smet (1989a, 1989b) recorded 31 morphological species for waterbodies of Santa Cruz Island, and Segers (1991) identified 14 species in Santa Cruz and San Cristobal islands. At present, the rotifer fauna of the Galapagos Islands is represented by 37 morphological species, and this list does not include any representative of the genus *Keratella*. This genus is of particular interest considering that it contains a group of rotifers rather exceptionally wide array of examples of species of biogeographical interest (Segers and De Smet, 2008).

In this note, we report the presence of a representative of the rotifer *Keratella cochlearis* (Gosse, 1851) species aggregate in El Junco Lake, a freshwater crater lake in the Galápagos Islands (Fig. 1).

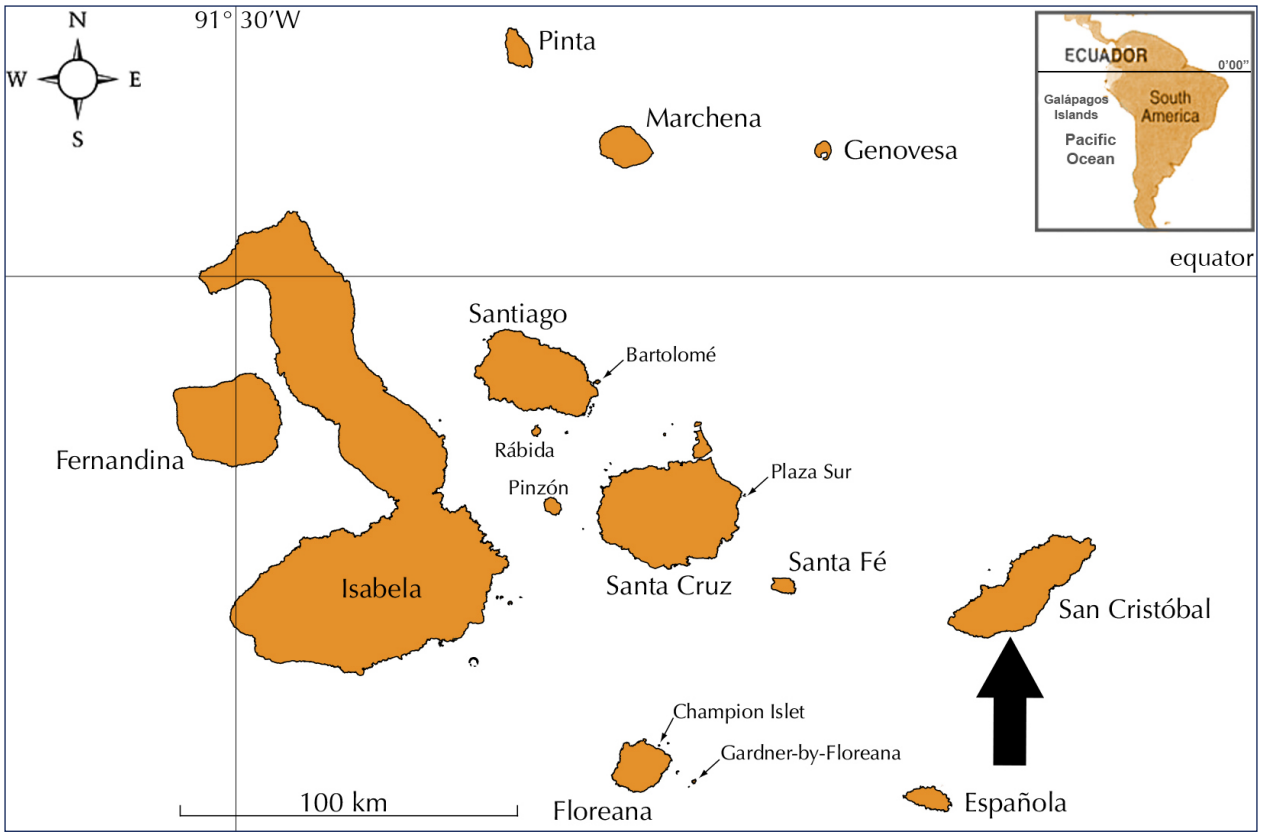

Figure 1. Map of the Galápagos Islands showing locations of San Cristóbal Island and Lake El Junco.

Methods

Our specimens originate from El Junco Lake, on San Cristobal Island, which is at an altitude of 675 m. The lake has an area of 60,000 m^2 and a volume of 360,000 m^3, equivalent to about 34 million liters of water (Fig. 2). Its maximum width is 200 m and its maximum depth is 6 m. It is fed only by rainwater. In times of drought the depth decreases by as much as 3 m, and after heavy rains (during strong El Niño events) the water overflows through a channel that forms a stream. It is only natural freshwater lake in the archipelago. During the island's cold season, which extends from July to December, the climate is temperate, with temperatures that oscillate between 18 °C and 25 °C, strong winds, and mist, but in the hot season, from January to June, there is moderate rainfall and the temperature fluctuates between 22 °C and 31 °C. This lake was first studied in 1966 by Colinvaux (1968), and since then, it has been central to numerous paleoecological studies designed to reconstruct the climatic history of the islands (Bush et al. 2010, Restrepo et al. 2012). The water in the lake has a transparency of 2 m (Secchi disc) and is acidic, a result of being dyed by humic acids. The lake is oligotrophic, with very soft water. Phosphorus and nitrogen are very low. In 1966 and 1974 there were cattle grazing at the rim of the crater, and this may account for slightly higher nitrogen levels. The lake is polymictic with oxygen to the bottom and uniform water temperature (Colinvaux 1968, Steinitz-Kannan et al. 1983).

Our samples were collected during the years 1977, 1978, 1984, 1986, 1991 and 2004 using a standard plankton net (63 µm) and fixed with Lugol Iodine. Collections were made by both horizontal hauls from the center of the lake towards the shore along a radius of the lake, by vertical hauls at the center of the lake from our coring platform, and at 2 stations near shore. In the laboratory, we dyed the specimens with Red Rose Bengala and analyzed them using a compound microscope. Identifications were made following Koste (1978) and Turner (1988). Microphotographic images and measurements were made with NIS-Elements D software. Voucher specimens were deposited in collection of aquatic invertebrates of Laboratorio de Medio Ambiente, Escuela Superior Politécnica del Litoral (LMA-ESPOL), Guayaquil, Ecuador.

Results

New records. Ecuador: Galapagos: San Cristóbal Island: Lake El Junco (00°53′42″ S, 089°28′48″W), collected by M. Steinitz-Kannan, 2 February 2004 (LMA-ESPOL-001, 10 parthenogenetic females), 11 September 2004 (LMA-ESPOL-002, 5 parthenogenetic females).

Parthenogenetic specimens belonging to the *Keratella cochlearis* aggregate were found in 2 samples from 2004. This organism did not occur in any of the samples collected in 1977, 1978, 1984, 1986, and 1991. This record is the first from the Galápagos archipelago, and it is separated by at some 950 km from the nearest localities of the species on the South American continent.

Identification. According to Alhstrom (1943), the lorica in this taxon is sculptured in a characteristic fashion, with

Figure 2. Photograph of Lake El Junco, San Cristóbal Island, Galápagos Archipelago. View from shore in 2004.

a median frontal facet and a middorsal ridge, and when it is visible, it always has at least 1 pair of nearly symmetrical median facets (Fig, 3C). The *K. cochlearis* aggregate is diagnosed by (1) presence of 6 anterior lorica spines (Fig. 3B), (2) a single caudal spine present (Fig. 3D) and, most importantly (3) presence of a characteristic cross-shaped delineation between the pairs of antero-carinal and postero-carinal facets (Fig. 3A). Minute spinules on the caudal spine are present (Fig. 3D). Body length of our specimens was between 160 and 286 µm and caudal spine length was between 53 and 95 µm. Judging from the number and pattern of lorica facets, and shape and disposition of the anterior and posterior spines and of the lorica our specimens correspond to the typical morphological variant of *K. cochlearis*

Discussion

The taxonomy of *K. cochlearis* is particularly problematic and in urgent need of revision, as reflected by the numerous subspecies and infrasubspecific variants in the aggregate (Segers 2007). This is mainly because it is highly morphologically variable, both in the length of the caudal spine and the degree of the development of the lorica pustulation (among other features), due to biotic and abiotic factors (Pejler 1980, Hoffman 1983, Conde-Porcuna et al. 1993, Bielañska- Grajner 1995, Diéguez et al. 1998, Xi et al. 2011, Ge et al. 2016). In addition to a number of closely related and morphologically distinct regionally endemic taxa (Segers and De Smet, 2008), the results of a recent molecular analysis indicate the presence of cryptic diversity within the taxon (Cieplinski et al. 2017). In the absence of a solid taxonomy based on conclusive molecular and morphological information

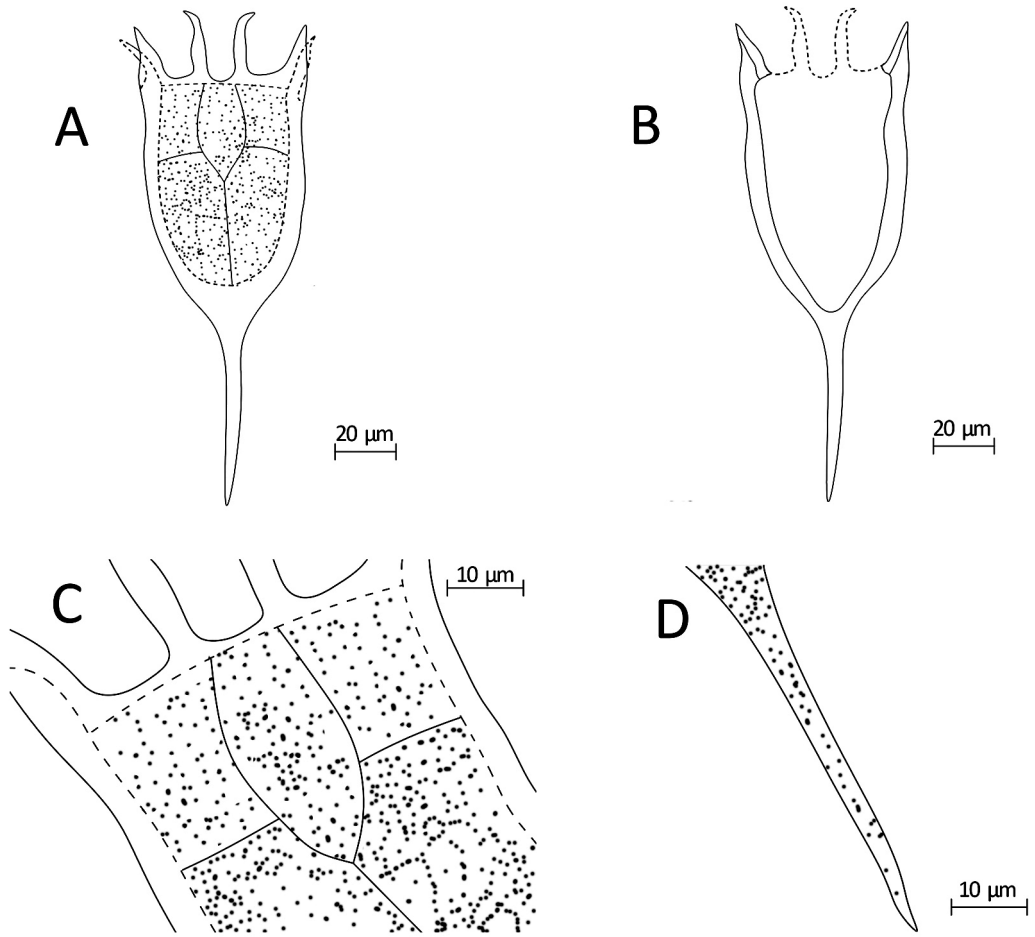

Figure 3. Specimen of *Keratella cochlearis* species aggregate collected in El Junco Lake, Galápagos in 2004. **A.** Dorsal view. **B.** Ventral view. **C.** Anterior region. **D.** Caudal spine.

and our limited information on the population in Lake El Junco, we suggest referring to the Galápagos specimens as "*Keratella* (*cochlearis*) species aggregate" in line with Article 6.2 of the International Code of Zoological Nomenclature (http://www.iczn.org/iczn/index.jsp).

Our Galápagos specimens are morphologically indistinguishable from the typical variant of *Keratella cochlearis*, which is considered cosmopolitan (Segers and De Smet 2008) and is common in continental Ecuador (Koste and Böttger 1989, 1992) and other regions of the Neotropics (Koste and José de Paggi 1982, Turner 1988, José de Paggi and Koste 1995, Vásquez et al. 1998, Garrafoni & Lourenço 2012, Ferrando and Claps 2016).

The occurrence of *K. cochlearis* only in samples from 2004 seems to suggest that the arrival and colonization of Lake El Junco is recent and probably may have occurred between 1991 and 2004. Segers (1991) identified rotifer species but did not record *K. cochlearis* in samples collected in 1988 in this lake and in another waterbody connected with it. His observations support this hypothesis. Our record from San Cristóbal Island, 950 km from the South American continent, is further consistent with the high dispersal ability of many rotifers. Among the means of dispersion of rotifers indicated by Segers and De Smet (2008), birds and human activities emerge as most plausible mechanisms in this particular case of colonization. The Galapagos Archipelago is frequented by about 27 species of migrant bird species (Windenfeld 2006) and the number of human visitors to the island has increased exponentially during the last 30 years. According to data of Direction of National Park Galápagos, Ecuador (http://www.galapagos.gob.ec/estadistica-de-visitantes), the number of visitors to the islands increased by about 300% between 1991 and 2004. In addition, the resident population of Puerto Baquerizo, the capital of the Province of Galápagos on San Cristobal Island has also greatly increased since early 2000. Accordingly, we hypothesize that *K. cochlearis* reached Lake El Junco through either zoochory by migrating birds or carried by tourists or residents. A more detailed study including molecular characterization of the *K. cochlearis* population would, however, be needed to test this hypothesis.

Acknowledgements

We thank the reviewers of an earlier version of this manuscript for their suggestions and constructive. We also thanks the staff of the Centro del Agua y Desarrollo del Agua de la ESPOL for laboratory support. Plankton collections on the Galapagos, including El Junco lake were funded by the US National Science Foundation, NOAA, and National Geographic grants to MSK and her colleagues. We thank the Charles Darwin Research Station and the Galápagos National Park for providing logistic support including permits to study El Junco Lake (Proyecto N° PC 08-04). We especially thank María Belén López for help with the map and drawings.

Author's Contributions

MS-K collected the species; CL, MS-K and HS contributed to the discussion and wrote the text.

References

Ahlstrom EH (1943) A revision of the Rotatorian genus *Keratella* with descriptions of three new species and five new varieties. Bulletin of the American Museum of Natural History 80: 411–457.

Bielañska-Grajner I (1995) Influence of temperature on morphological variation in populations of *Keratella cochlearis* (Gosse) in Rybnik Reservoir. Hydrobiologia 313 (1):139–146. https://doi.org/10.1007/BF00025943

Bush MB, Colinvaux PA, Steinitz-Kannan M, Overpeck JT, Sachs J, Cole J, Collins A, Conroy J, Restrepo A, Zhang I (2010) Forty years of paleoecology in the Galapagos. Galapagos Research 67: 55–61.

Cieplinski A, Weisse T, Obertegger U (2017) High diversity in *Keratella cochlearis* (Rotifera, Monogononta): morphological and genetic evidence. Hydrobiologia 796 (1): 145–159. https://doi.org/10.1007/s10750-016-2781-z

Colinvaux P (1968) Reconaissance and chemistry of the lakes and bogs of Galápagos Islands. Nature 219: 590–594.

Conde-Porcuna J, Morales-Baquero MR, Cruz-Pizarro L (1993) Effectiveness of the caudal spine as a defense mechanism in *Keratella cochlearis.* In: Gilbert JJ, Lubzens E, Miracle MR (Eds) Rotifer Symposium VI. Developments in Hydrobiology 83. Springer, Dordrecht, 283–287. https://doi.org/10.1007/978-94-011-1606-0_37

De Smet W (1989a) Rotifera uit de Galápagoseilanden. Natuurwetenschappelijk Tijdschrift 69: 110–131.

De Smet W (1989b) Addendum bij: Rotifera uit de Galápagoseilanden. Natuurwetenschappelijk Tijdschrift 71: 80–81.

Diéguez M, Modenutti B, Queimaliños C (1998) Influence of abiotic and biotic factors on morphological variation of *Keratella cochlearis* (Gosse) in a small Andean lake. In: Wurdak E, Wallace R, Segers H (Eds) Rotifera VIII: A Comparative Approach. Developments in Hydrobiology 134, Springer, Dordrecht, 289–294. https://doi.org/10.1007/978-94-011-4782-8_37

Dirección Parque Nacional Galápagos, Ecuador (2017) http://www.galapagos.gob.ec/estadistica-de-visitantes. Accessed on 2018-02-16.

Ferrando N, Claps M (2016) A revised and updated checklist of Monogononta rotifers from Argentina. Check List 12 (4): 1942. https://doi.org/10.15560/12.4.1942

Garraffoni A, Lourenço A (2012) Synthesis of Brazilian Rotifera: an updated list of species. Check List 8 (3): 375–407. https://doi.org/10.15560/8.3.375

Ge Y, Xi Y, Ma J, Xu D (2016) Factors Influencing Morphological Characteristics of *Keratella cochlearis* in Lake Tingtang. Proceedings of the National Academy of Sciences of India Section B Biological Sciences 88: 421. https://doi.org/10.1007/s40011-016-0768-1

Hofmann W (1983) On temporal variation in the *Keratella cochlearis* the question of Lauterborn cycles. Hydrobiologia 101: 247–254. https://doi.org/10.1007/BF00009882

ICZN (1999) International Code of Zoological Nomenclature. 4th edition. The International Trust for Zoological Nomenclature, London. http://www.iczn.org/iczn/index.jsp. Accessed on: 2018-2-16.

José de Paggi S, Koste W. (1995) Additions to the checklist of rotifers of the superorder Monogononta recorded from Neotropics. International Revue der gesamten Hydrobiologie und Hydrographie 80: 133–140. https://doi.org/10.1002/iroh.19950800116

Koste W, José de Paggi S (1982) Rotifera of the superorder Monogononta recorded from Neotropics. Gewässer und Abwässer 68/69: 71–102.

Koste W, Böttger K (1989) Rotatorien aus Gewässer Ecuadors. Amazoniana 10 (4): 407–438.

Koste W, Böttger K (1992) Rotatorien aus Gewässer Ecuadors II. Amazoniana 12 (2): 263–303.

Koste W (1978) Rotatoria. Die Radertiere Mitteleuropas, 2nd ed. Gebrueder Borntraeger, Berlin, vol. 1, 673 pp; vol. 2, 476 pp.

Pejler, B (1980) Variation in the genus *Keratella*. Hydrobiologia 73: 207–213.

Restrepo A, Colinvaux P, Bush M, Correa A, Metrio, J, Conroy MR, Gardener P, Jaramillo M, Steinitz-Kannan M, Overpeck J (2012) Impacts of climate variability and human colonization on the vegetation of the Galápagos Islands. Ecology 93: 1853–1866 https://doi.org/10.1890/11-1545.1

Segers H (1990) Contribution to the knowledge of the rotifer fauna of the Galápagos Islands. Biologisch Jaarboek (Dodonaea) 58: 113–119.

Segers H (2007) Annotated checklist of the rotifers (phylum Rotifera) with notes on nomenclature, taxonomy and distribution. Zootaxa 1564: 1–104.

Segers H, Dumont H (1993) Zoogeography of Pacific Ocean islands: a comparison of the rotifer faunas of Easter Island and the Galápagos archipelago. In: Gilbert JJ, Lubzens E, Miracle MR (Eds) Rotifer Symposium VI. Developments in Hydrobiology, 83. Springer, Dordrecht, 475–489. https://doi.org/10.1007/978-94-011-1606-0_63

Segers H, Smet W (2008) Diversity and endemism in Rotifera: a review, and *Keratella* Bory de St Vincent. Biodiversity and Conservation 17: 303–316. https://doi.org/10.1007/s10531-007-9262-7

Steinitz-Kannan M, Collinvaux P, Kannan R (1986) Limnological studies in Ecuador: 1. A survey of chemical and physical properties of Ecuadorian lakes. Archiv für Hydrobiologie 65 (Supplement): 61–105.

Turner P (1988) *Keratella* rotifers found in Brazil, and a survey of Keratella rotifers from Neotropics. Amazoniana 10 (2): 223–236.

Vásquez E, Pardo M, Zoppi de Roa E, López C (1998) Rotifer fauna from Venezuela. Amazoniana 15 (1/2): 11–24.

Windenfeld D (2006) Aves, the Galapagos Islands, Ecuador. Check List 2 (2): 1–27. https://doi.org/10.15560/2.2.1

Xi Y, Jin H-J, Xie P, X, Huang X-F (2011) Morphological variation of *Keratella cochlearis* (Rotatoria) in a shallow, eutrophic subtropical Chinese lake. Journal of Freshwater Ecology 17 (3): 37–41. https://doi.org/10.1080/02705060.2002.9663919