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BRIEF COMMUNICATION

Exotic species of rotifers in Mexico

S. NANDINI[1,*], S.S.S. SARMA[2] AND R.L. WALLACE[3]

[1]LABORATORIO DE ECOLOGÍA ACUÁTICA, UMF, FES IZTACALA, UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO, AV. DE LOS BARRIOS NO. 1, AP 314, LOS REYES, TLALNEPANTLA, ESTADO DE MÉXICO 54090, MEXICO , [2]LABORATORIO DE ZOOLOGÍA ACUÁTICA, UMF, FES IZTACALA, UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO, AV. DE LOS BARRIOS NO. 1, AP 314, LOS REYES, TLALNEPANTLA, ESTADO DE MÉXICO 54090, MEXICO AND [3]DEPARTMENT OF BIOLOGY, RIPON COLLEGE, 300 SEWARD STREET, RIPON, WI 54971, USA

*CORRESPONDING AUTHOR: nandini@unam.mx

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Mexico is a megadiverse country, with 10% of all known species found within its borders. The CONABIO catalogue registers rotifers as one of the best-studied groups of animals in Mexico, with the number of species recorded representing 18% of the total global rotifer fauna. However, this registry does not record a single exotic species of Rotifera in Mexico. Here, we confirm the presence of six species of exotic rotifers in Mexican inland waters, highlighting the case of *Kellicottia bostoniensis*, recorded in Mexico since the 1990's, but never as an exotic species.

KEYWORDS: *Kellicottia bostoniensis*; distribution; biogeographical regions

INTRODUCTION

The invasion of micrometazoans (cladocerans, copepods and rotifers) into permanent aquatic habitats usually starts with records of very low abundances in areas where researchers have not previously noted the species (Muzinic, 2000). Because their occurrence is rare, researchers ignore them or regard them as scientific curiosities and assume that they do not pose threats to established species or the community structure as a whole (Sagoff, 2005). However, colonization and expansion can be a long-term process, with many intrusions being unsuccessful, or at least their effect is not quantifiable with current ecological tools (Vera-Escalona *et al.*, 2019). Over time, reports of the exotic species may increase and become more widespread, at which point researchers infer that the invader is rapidly expanding into other habitats (Havel *et al.*, 2002).

One of the consequences of the introduction of exotic species to a system may be to restructure the trophic dynamics (Arcifa *et al.*, 2020). If the conditions are suitable, the exotic species will flourish, producing substantial populations. The recruit may successfully out-compete resident species for resources, with the result being species replacement. This may occur without causing quantifiable changes in the composition of local taxa; that is, the alien species is ecologically fungible with the one it replaces; this concept has been referred to as compensatory colonization (Brown *et al.*, 2001).

Mexico is one of 17 megadiverse countries, with 10% of all known species found within its borders (Llorente-Bousquets and Ocegueda, 2008). Since 1992, the Federal Agency, National Commission for the Knowledge and Use of Biodiversity (CONABIO), has undertaken a systematic study of biodiversity in Mexico, including exotic species. The CONABIO catalogue registers rotifers as among the best-studied groups of animals in Mexico with the number of species recorded comprising 18% of the total rotifer fauna. However, none are catalogued as exotic or invasive (https://www.gob.mx/semarnat/documentos/anexo-ii-listado-de-invertebrados).

According to Simberloff (2013), exotic species (also called alien, non-indigenous, non-native) are those present in a region but do not belong there based on biogeographical studies, while invasive species are introduced species with recorded negative impacts on the biodiversity of the region (Simberloff, 2013). We used these terms based on the biogeographical information in Segers (2007). It has been shown that the invasion of non-native (exotic) species is an important factor in loss of biodiversity (Mantovano *et al.*, 2021; Muirhead and MacIsaac, 2005). The Mexican CONABIO catalogue shows that rotifers are among the best studied animals in the country but does not record any exotic species of Rotifera in Mexico (Ramírez-Albores *et al.*, 2019). Here, we present a short history of the study of rotifers in Mexico, highlighting the presence of exotic species of this phylum in Mexican inland waters. We emphasize the case of *Kellicottia bostoniensis*, which we find with increasing frequency and dominance in several reservoirs.

RESULTS AND DISCUSSION

Rotifer research in Mexico began close to a century ago. Ahlstrom (1932) made the first wide-ranging description of the rotifer fauna of Mexico, but it was limited to central and southern Mexico. Later studies were sporadic (e.g. Rico-Martínez and Silva-Briano, 1993) until those initiated by S. S. S. Sarma, which resulted in a list of more than 300 species (Sarma, 1999). These studies were limited to selected water bodies from central and south-eastern Mexico. Since then, inventories of rotifer species from several Mexican water bodies have been published (Sarma *et al.*, 2021). In this section, we highlight information available on selected species of rotifers that have been recorded outside their known range of distribution based on Segers (2007).

About 400 species of rotifers have been recorded in Mexico, with the most common families being Brachionidae, Lecanidae, Collothecidae, Lepadellidae, Notommatidae and Trichocercidae. However, a confounding factor is that species complexes are known to exist in rotifers, particularly in families Brachionidae, Epiphanidae and Lecanidae, although many of them have not been formally described. Thus, based on the current knowledge of the proportion of cryptic species, the actual number of extant species is unknown (Fontaneto *et al.*, 2009; Sarma *et al.*, 2021).

One of the first studies that reported the presence of non-native species of rotifers in Mexico was from the River Antigua in Veracruz State, which revealed three exotic taxa (Nandini *et al.*, 2017). *Notholca liepetterseni* Godske Bjorklund (1972) was first recorded in Espegrend, Bergen, Norway. It has also been reported from the Hudson River, USA, Canada and from brackish waters in Korea (Song and Kim, 1992). A marked seasonality in the occurrence of *N. liepetterseni* was reported in the Hudson River, with populations present only from January to April. We also observed populations of this species in the River Antigua, Veracruz during January to March (Nandini *et al.*, 2017). The conductivity at that site ranged from 900 to 1800 μs cm^{-1}, indicating brackish water conditions.

Lecane yatseni Wei and Xu, 2010 was described from a freshwater body on an island in the Pearl River Estuary almost a decade ago. However, we found a form of *Lecane* closely resembling that species in the Antigua River close to the Gulf of Mexico. Further confirmation based on morphometry and molecular analyses is pending. Because this species is very rare, for the present, we suggest that it should be considered an exotic rather than an invasive species.

Euchlanis mikropous Koch-Althaus, 1962 was described from Lake Stechlin in Germany. This species is characterized by extremely short toes (Koch-Althaus, 1962). We found a species of *Euchlanis* in the Antigua River closely resembling the first description of *E. mikropous* without toes (Nandini *et al.*, 2017). Experimental studies showed that this species cyclically loses and regains its toes during successive generations (Nandini and Sarma, 2019). Molecular studies are needed to confirm whether *E. mikropous* from Lake Stechlin and *E.* cf. *mikropous* from the Antigua are the same species or should be separated. These species occur seasonally and in low numbers under natural conditions; it remains to be seen whether they could displace local taxa and become invasive (Nandini *et al.*, 2017; Nandini and Sarma, 2019). It is also important to study the autecology of exotic species; such studies allow us to assess their potential to invade new habitats and the biological consequences of that invasion, both in terms other residents and the species itself. For instance, we observed that *E. mikropous* have morphotypes that cycle between individuals with toes and those without, but this phenomenon was observed only after the species had been cultured (Nandini and Sarma, 2019).

Sphyrias lofauna (Rousselet, 1910), a species from the African and Pacific regions (Segers, 2007), was recorded only once from the waterbody Zirahuén in the State of Michoacán in the late 1990's, but it has not been reported since then (Sarma and Elías-Gutiérrez, 1999).

Horaella thomassoni Koste, 1973 was first reported more than 25 years ago from Central Mexico (Rico-Martínez and Silva-Briano, 1993). Previously, this species was reported in Brazil by Koste (1973), and since then, it has been spreading northwards. It is now frequently observed in reservoirs, even those situated at high altitude such as those in Valle de Bravo (personal observations) and Madín in the State of Mexico (Moreno-Gutiérrez *et al.,* 2018). Thus, the range of distribution of *H. thomassoni* has expanded from the Neotropical region into biogeographic provinces of the Nearctic region (Morrone *et al.,* 2017; Sarma *et al.,* 2021).

The rotifer genus *Kellicottia* is a brachionid member with two well-characterized species. *Kellicottia longispina* was first described in from north-eastern USA in 1879 as *Anuraea longispina* by Kellicott and *K. bostoniensis* as *Notholca bostoniensis* by Rousselet in 1908. Harring (1913) erected the genus *Kellicottia*, into which he placed these two species. *Kellicottia longispina* and *K. bostoniensis* are now recognized as introduced to the Palearctic and Neotropical regions (Segers, 2007). Mexico is divided into 14 biogeographical regions, 5 with Nearctic characteristics, 4 with Neotropical characteristics and 5 that share both Nearctic and Neotropical characteristics (Morrone *et al.,* 2017). With this rich geodiversity, the potential for a rich rotifer biodiversity is high, including the presence of exotic species.

Since their first descriptions, both species of *Kellicottia* spread rapidly into other regions. In 1888, the first specimens of *K. longispina* were observed in England (Edmondson and Litt, 1989) and *K. bostoniensis* was first observed in Sweden and Finland in 1943 (Arnemo *et al.,* 1968). Thus, both species of *Kellicottia* are considered invasive (Bomfim *et al.,* 2016) and are now widely spread in Europe and Asia (Pociecha *et al.,* 2016; Yang and Min, 2020; Zhdanova *et al.,* 2016) but have not been recorded from Australia (Bomfim *et al.,* 2016). In the USA, it is widespread and has been recorded from Argentina for more than two decades (José de Paggi, 2002). In the recent estimate of the potential invasibility of *K. bostoniensis* across the globe, Mexico received essentially no discussion (Mantovano *et al.,* 2021). A study, based on a systematic review of papers published on rotifers in Mexico (Sarma *et al.,* 2021), reports several species outside

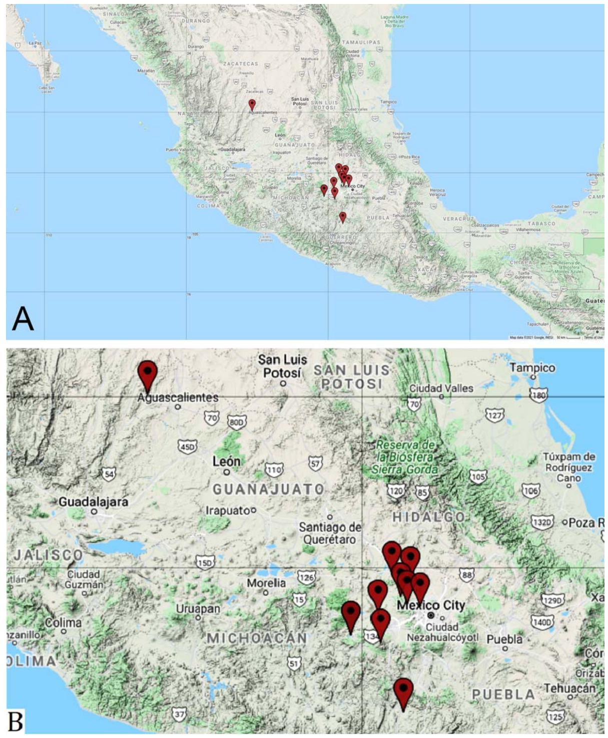

Fig. 1. Distribution of *Kellicottia* in Mexico (Image from Google Maps and locations indicated by the authors).

their known range of distribution but does not include *Kellicottia.*

Kellicottia longispina and *K. bostoniensis* have been reported from water bodies in the Nearctic and Neotropical zones of Mexico (please see Sarma *et al.,* 2021). *Kellicottia bostoniensis* is generally considered to be an exotic species when found outside the north-eastern USA. Several studies report an increase in the distribution and spread of *K. bostoniensis* in South America (Bomfim *et al.,* 2016; José de Paggi, 2002). Although this species has been reported from Mexico (Sarma *et al.,* 2021 and references therein), it has not been recognized as an exotic/invasive species in the country (Nandini *et al.,* 2008; Rico–Martínez and Silva-Briano, 1993; Vázquez-Sánchez *et al.,* 2014). We have observed *K. bostoniensis* (Fig. 2) in samples from the Chihuahuan desert region, Nearctic Trans Mexican Volcanic belt and from the Neotropical regions (Balsas) (Nandini *et al.,* 2008; Rico-Martínez and Silva-Briano, 1993; Vázquez-Sánchez *et al.,* 2014). Since *K. bostoniensis* was recorded from Nearctic and Neotropical regions of Mexico, the fact that it could be considered exotic/invasive was overlooked. This is evident from Mantovano *et al.* (2021) where the only indication of its invasion into Mexico was all but obscured within their global map (i.e. Fig. 1). We note that their map of

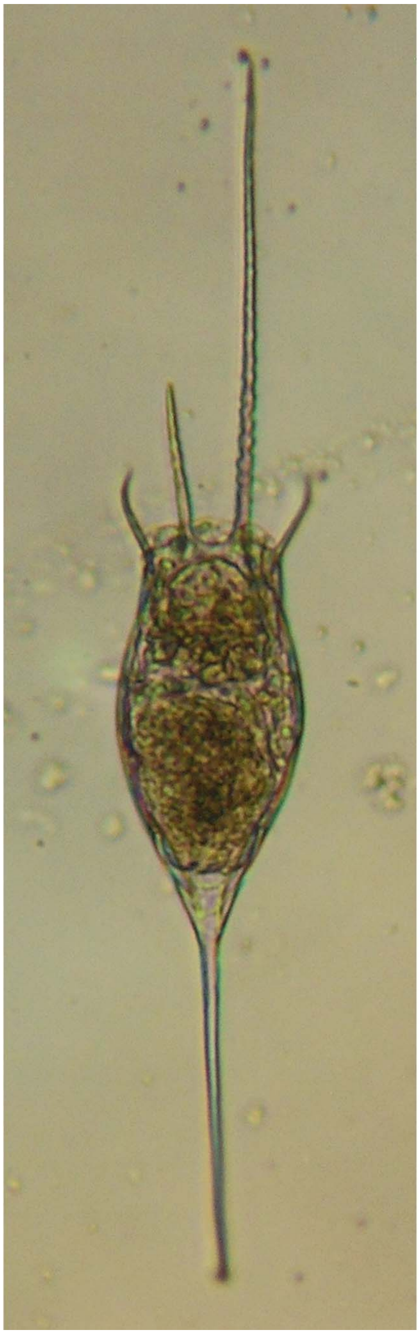

Fig. 2. *Kellicottia bostoniensis* (Villa Victoria Reservoir, State of Mexico).

"climatic and environmental suitability for *K. bostoniensis*" expansion indicates that it could expand within Mexico but that possibility was not discussed. We do not fault Mantovano *et al.* (op. cit.) for this—their contribution is very valuable. The issue is that no information is available on its distribution in the CONABIO catalogue. Our contribution emphasizes that oversite lies with the CONABIO catalogue and we note that *K. bostoniensis* is expanding its range in Mexico.

Experimental and field studies are necessary to confirm the invasiveness of species and their effect on resident fauna and flora. Recent studies on *K. bostoniensis* present divergent views on that subject. Oliveira *et al.* (2019) show that *K. bostoniensis* has a negative effect on microzooplankton communities in samples from Osmar Lake in Brazil, while based on analysis of foraging behavior and guild ratios Arcifa *et al.* (2020) predicted that it would have no adverse effect on local zooplankton communities. It is possible that the long spines of this rotifer could act as a deterrent against fish predation, thereby reducing the secondary productivity in inland waters. Although *K. longispina* was observed in field collections, we now find *K. bostoniensis* more frequently in our zooplankton samples.

CONCLUSIONS

As our understanding of the distribution of rotifers increases, we are recording more exotic species in several inland waterbodies. This could be due to an increase in global transport and temperature changes associated with climate change. Our study highlights the need for thorough taxonomic surveys of rotifers in Mexico (Sarma, 1999; Sarma *et al.,* 2021). Autecological and molecular studies are also important in confirming the presence of exotic species. Ecological research on the impact of these species on local communities is urgently needed.

AUTHORS' CONTRIBUTION

Development of concept: S.N. and S.S.S.S.; writing of the manuscript: S.N., S.S.S.S. and R.L.W.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

DATA AVAILABILITY

Data will be made available, on request, by the corresponding author.

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