Spatial distribution overview of rotifers in the Yucatán peninsula, México

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ABSTRACT
The spatial distribution of rotifers in the aquatic ecosystems of the Yucatán peninsula is unclear. The peninsula is a karstic platform with heavy anthropogenic activity that presently puts pressure on and increases the fragmentation of aquatic systems. As the distribution of rotifers is unknown in this region, this study was performed to model spatial distribution of rotifers. Based on the analysis of their absence and presence in aquatic systems, using data from specimens collected in the field and bibliographic information from 1997 to 2018, our goal was to provide protection agencies as well as local and regional users with information on the distribution of microorganisms in the aquatic systems. With this material, an 877-record database with was produced. The bioregion outlined is an area in which 43 genera and 140 species of been observed; the study area contains 47.85% of all the rotifer species reported in Mexico. The essential genera in this bioregion are Brachionus with nine species, Keratella with three and Lecane with 44. In these three genera, we observed two morphotypes of rotifers: a small type in the southern zone and a large type in the northern zone.

1. Introduction
The reproductive and adaptive capacities of rotifers enable them to inhabit freshwater and marine aquatic ecosystems around the world. Moreover, rotifers account for approximately 30% of the diversity and biomass of zooplankton in water; therefore, they can be used as indicators of the distribution and biological connectivity of species (Fontaneto, 2019; Fontaneto et al., 2012; Segers, 2008). However, one problem with the analysis of patterns in microorganisms is that their diversity can be difficult to assess if there is no reliable data on the distribution of all the existing species. For example, abiotic and biotic vectors potentially disperse rotifers overland, namely: wind, rain, water or other organisms. Many studies have analyzed dispersal vectors, for the case of rotifers an instance is aquatic birds, which transport rotifers from one water body to another (Zhdanova et al., 2016). In particular, studies on the biodiversity of rotifers in the geographical area of the Yucatán peninsula, carried out by A. García-Morales and Elias-Gutiérrez (2004) and Cervantes-Martinez (2005), have focused on south-eastern Mexico, i.e. the states of Chiapas, Veracruz, Tabasco, Campeche, Yucatan and Quintana Roo; the last three are comprised in the Yucatán peninsula. One hundred nineteen rotifer species were included in these two reports and out of them 68 were new records. The largest number of species reported was for the genus Lecane. Though, the distribution of rotifers has not been fully described for the northwestern part of Quintana Roo and other regions in northern and central Yucatán peninsula. The difficulties faced to find rotifer’s distribution patterns become complex because there are regions in which neither collection efforts nor species identification have been comprehensively carried out. Also, owing to the scarcity of reproductive isolation analyses, the biogeographic approach to the distribution of rotifers must be carefully analyzed. The first hypothesis may be tested locally, then regionally and finally, at global level (Fontaneto et al., 2012).

The Yucatán peninsula is a platform of great cultural, ecological and socio-economic value. It is a karstic hydrogeological system with fractures, caves and cenotes (sinkholes), which allow a great permeability and underground flow of water. Most of its ecosystems depend on groundwater, which is not surprising, as karstic systems comprise between 7 and 12% of the earth’s continental surface and supply about a quarter of freshwater for human use worldwide (Schmitter-Soto et al., 2002; Torrescano-Valle & Islebe, 2015). Some
authors, such as Aguilar et al. (2016), reported 6717 depressions with a total area of 454 km² and 750 karst features as potential niches for aquatic species; indeed, several works report a high diversity of aquatic biota in the Yucatán peninsula (Álvarez-Cadena et al., 2007; Herrera-Silveira & Comín, 2000; Suárez-Morales et al., 2013).

In this way, to understand the distribution and diversity of microorganisms such as rotifers in aquatic ecosystems, we need to focus on describing the shapes and sizes of the species, understanding the mechanisms involved in speciation, identifying reproductive barriers, differentiating mating behaviors, and also on the viability of hybrids and genetic variation. In order to further study the differentiation of ecological niches, other variables should be included, e.g. food density and type, competitions between species in life-table experiments, as well as the genetic basis for variation in ecological adaptation.

Although the Yucatán peninsula presents the highest diversity of aquatic biota in the south of México, and the fact that freshwater biota from Neotropical regions is among the most diverse in the world and offers the possibility of using various species as ecological indicators (Dahms & Van Den Brink, 2010). Therefore, the main goal of the present study was to explore the spatial distribution of rotifers in the north-western Yucatán peninsula (sixteen genera), and additionally, with such patterns to define rotifer distribution areas (vector polygon), i.e. prospective bioregions. These two goals for the use of rotifer distribution in the Yucatán peninsula offer a baseline reference for ecologists, geneticists, socio-economic researchers and people in general to make environmental legislation decisions of aquatic microorganisms.

2. Materials & methods

2.1 Bibliographic data collected

We reviewed rotifer records for south-eastern Mexico, with an emphasis on the Yucatán peninsula, from 1997 to 2018. A Google Scholar search was run using rotifers and Yucatán peninsula as keywords. We also developed a database with information on distribution, temperature, pH and conductivity preferences for 877 individual rotifers (a total of 45 genera and 140 species). Descriptive statistics were produced for quantitative variables using Statistica® version 6.

2.2 Collection and identification of rotifers

As a part of studies on rotifer distribution in the Yucatán peninsula (Project #2944 CONACYT) 100 zooplankton samples were collected in the north-eastern and south-eastern Yucatán peninsula from 2014 to 2018. Samples were gathered using a Wisconsin sampler with a 45-µm aperture mesh. In each site, the geographic coordinates were recorded in the universal transverse Mercator system using a Garmin eTrex® 10 global positioning system. Three zooplankton samples were collected from each site. 100 ml of the total sample volume was preserved in formalin at 5%, 100 ml were preserved in 96% alcohol, while 50 ml were unpreserved (live specimens). The samples were transported to the Ecotoxicology Laboratory in the Center of Scientific Research of Yucatán, in the Water Sciences Unit, Cancun Campus, Quintana Roo, Mexico. The species were identified resorting to specialized pictorial and dichotomy keys: Koste (1978), Stemberger (1979), and Segers (1995).

2.3 Morphometry of rotifers

Linear traditional morphometry measurements were performed on rotifers Lecane bulla, Keratella americana, Philodina cf roseola and Brachionus cf ibericus, this last was the most frequent in the samples with an excellent distribution. This was carried out to characterize morphotypes in the Yucatán peninsula. Only females were selected from the samples preserved in formalin at random by locality (we decided to only use females because in environmental samples males are difficult to find and associate with the species, see Table 2). For photographs and measurements, rotifers were placed in glycerol and subsequently mounted on glass slides, according to Arroyo-Castro et al. (2019). In each photograph, the length of the body was measured using software AxioVision SE64Rel. 4.8 Inc., 2003.

2.4 Distribution analysis and definition of the bioregion

The following vector layers (which refer to the geographic data on the presence of rotifers represented as geographic coordinates or water body delimitation polygon) were utilized: rotifer diversity, water bodies and the borders of the Yucatán peninsula states. A vector layer of water bodies was used to generate a buffer to make an intersection with the interpolation of rotifer dispersion probability. All of this was generated using the geoprocessing software tool QGIS 2.14.0-Essen with Grass. Vector layers generated with the following parameters were used: buffer distance for rotifers was 3 km, while the buffer distance for water bodies was 10 km, which was established according to the coordinates of the reference system map and the classification of exokarstic shapes of dolines, uvalas, and
poljes reported by Aguilar et al. (2016). We chose the option of QGIS item software to dissolve the result of the buffer. Later on, a spatial superposition of the intersection of the vector layers was made using the buffers of rotifers and water bodies; subsequently, data were superposed on the vector layer of the states of the Yucatán peninsula. Finally, we produced the map and defined the polygon vector of rotifer distribution. All geoprocessing procedures were performed in QGIS 2.14.0-Essen with Grass software.

2.5 Modelling the spatial distribution of rotifers in the Yucatán peninsula

The spatial distribution modeling of the rotifers with 19 bioclimatic variables (10-km pixel size) was performed with Maxent 3.4.1 software. The variables were taken from WordClim Global Climate Data (http://worldclim.org/). Three physical and chemical variables of water (1-km pixel size) were developed from the rotifer database. The modeling was performed from a general approach to identify areas of dispersal and connectivity. For the modeling, we used the logistic output format and adjusted the conditions from the initial training model: 10 replicates with subsample, 5000 maximum iterations, 25% random test percentage and convergence threshold of 0.00001. First, we checked the collinearity of variables and those highly correlated (r > 0.85 Pearson correlation coefficient) were excluded from the models. As a result of the initial analysis of the logistic modeling with Maxent 3.4.1, the analysis of the distribution was carried out only with the four bioclimatic variables that contribute with values greater than 10% (BIO5, BIO14, BIO17 and BIO19); on the other hand, three physical and chemical variables were used: conductivity, temperature and pH. The modeling was performed for all species of rotifers. Then, the analysis was replicated with sixteen genera, since these were the most abundant in the 100 samples, with the largest distribution over the Yucatán peninsula and with the best previous A.U.C. values in the spatial distribution analysis with QGIS 2.14.0-Essen, in the database of this study (see supplementary material). Jackknife analysis and response curves were utilized as statistical support to find out the variables that reduce the reliability of the model. We used the area under the Receiving Operator Curve (A.U.C.) to evaluate the best model performance. Finally, the best figures are presented according to area under the receiver operator curve (A.U.C.) values >0.60 (Hanley & McNeil, 1982). Values with this method range from 0 to 1; those close to one suggest a high probability of rotifer presence (red), whereas values close to zero have a low probability (blue).

Bioclimatic variables are derived from monthly temperature and rainfall values to generate more biologically meaningful variables, which are often used in species distribution modeling and related ecological modeling techniques. Bioclimatic variables represent annual trends (e.g. mean annual temperature, annual precipitation), seasonality (e.g. annual temperature and precipitation ranges) and extreme or limiting environmental factors (e.g. temperature of the coldest and warmest months, and precipitation of the wet and dry quarters/seasons). They are codes for the bioclimatic variables in the supplemental material.

3. Results

A database composed of 877 rotifer specimens was built. With this information, a bioregion distribution of rotifers that encompassed the biological corridor of rotifers in the Yucatán peninsula was outlined following two considerations: the spatial distribution and spatial intersection of rotifers with water bodies and their distribution model dependent on climatic variables, and physical and chemical characteristics of water. The genera found in the corridor as well as their physical and chemical values are listed in (Table 1). In total, 45 genera and 140 species were found in the biological corridor.

The corridor stretches from south-eastern Yucatán peninsula to the northwest, as illustrated in (Figure 1). The main genera in the corridor, with the greatest distribution, are Brachionus with nine species, Keratella with three and Lecane with 44. Based on the physico-chemical values of the water rotifers were collected: the water is slightly alkaline with conductivity values consistent with freshwater to brackish environments; mean water temperature was 27.72 ± 2.70°C (21.35–35°C, n = 679); mean pH was 8.05 ± 0.80 (5.6–9.6, n = 394); and, mean conductivity was 851.82 ± 210.10 µS/cm3 (210.10–4634.00 µS/cm3, n = 404). All data ± SD (ranges in parentheses).

The maps of the logistic modeling of sixteen genera rotifers distribution in the Yucatán peninsula are shown in (Figure 2) (according to the best modeling results). For these sixteen rotifers genera, our results indicate that four variables were the most important based on their percentage contributions. According to A.U.C. value, which indicates it is a good model, if the A.U.C values are high or close to one, indicated the model have a good probability of distribution of rotifers. The A.U.C. values for the distribution models of the sixteen genera are in (Table 2).

These variables were rainfall in the coldest quarter (BIO19) with 54.1%; rainfall in the driest quarter
Finally, the genus Keratella (Figure 2) is broadly distributed in the north-eastern and south-eastern Yucatán peninsula. The distribution of genus Lecane spp. is more specific, as noted in well-defined red, orange and yellow areas in (Figure 2).

In addition, the other modeling analysis including only with physical and chemical water variables, the A.
Figure 1. Bioregion of the buffer intersection of rotifer distribution and the presence of bodies of water (in green). This is referred to as the biological corridor for rotifers in the Yucatán peninsula. scale 1: 2,345,610. EPSG: 4326.

Figure 2. Global logistic distribution models for rotifers (by genus) in the Yucatán peninsula with bioclimatic variables. A color scale from red to blue is used; red indicates high distribution probability, while blue indicates there is no presence of the specimen.
Table 2. Percentage contributions of the bioclimatic variables and the area under the receiving operator curve (A.U.C.) to the best model performance for rotifers in from the Yucatán peninsula. Variables 2–7 correspond to temperature; variables 13–19 correspond to rainfall.

| Genus           | AUC  | V2   | V3   | V4   | V5   | V6   | V7   | V13  | V14  | V15  | V17  | V18  | V19  |
|-----------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Anaeuporis      | 0.95 | 19%  |      |      |      |      |      |      |      |      |      |      |      |
| Brachionus      | 0.86 |      |      |      |      |      |      |      |      |      |      |      |      |
| Cephalodella    | 0.94 |      |      |      |      |      |      |      |      |      |      |      |      |
| Colurella       | 0.93 |      |      |      |      |      |      |      |      |      |      |      |      |
| Euchlanis       | 0.99 |      |      |      |      |      |      |      |      |      |      |      |      |
| Hexarthra       | 0.97 |      |      |      |      |      |      |      |      |      |      |      |      |
| Keratella       | 0.93 |      |      |      |      |      |      |      |      |      |      |      |      |
| Lecane          | 0.82 |      |      |      |      |      |      |      |      |      |      |      |      |
| Lepadella       | 0.82 |      |      |      |      |      |      |      |      |      |      |      |      |
| Macrochaetus    | 0.82 |      |      |      |      |      |      |      |      |      |      |      |      |
| Mytinia         | 0.76 |      |      |      |      |      |      |      |      |      |      |      |      |
| Platiounus      | 0.82 |      |      |      |      |      |      |      |      |      |      |      |      |
| Platyas         | 0.90 |      |      |      |      |      |      |      |      |      |      |      |      |
| Polyarthra      | 0.95 |      |      |      |      |      |      |      |      |      |      |      |      |
| Pygura          | 0.91 |      |      |      |      |      |      |      |      |      |      |      |      |
| Philodina       | 0.98 |      |      |      |      |      |      |      |      |      |      |      |      |

U.C are 0.647 for all genera of rotifers; and particularly, 0.666 for Brachionus; 0.65 for Keratella; and, 0.608 for Lecane. In the modeling of the distribution of rotifers with the physical and chemical variables, temperature contributes with 11.2% to the explanation all the rotifers distribution, conductivity with 51.1%, and pH with 37.7%. For Brachionus, temperature contributes with 9.1%, pH with 36.1%, and conductivity with 54.8%. For Keratella, temperature contributes with 11%, conductivity with 34.2%, and pH with 54.8%. For Lecane, temperature explains 20.3% of the distribution, conductivity 71%, and pH 8.7%.

Finally, our morphometric analyses, shown in (Table 3), indicate that there are two morphotypes for Lecane bulla, two morphotypes for Keratella americana, and three morphotypes for the marine rotifer Brachionus cf ibericus; all of them belong to the class Monogononta, while for the Bdelloid rotifer class, Philodina cf roseola, two morphotypes were found. In general, a small morphotype is found in the southern zone of the Yucatán peninsula, while a large morphotype in the northern zone, either marine or freshwater. Furthermore, we found a medium morphotype for the rotifer Brachionus cf ibericus.

Table 3. Morphotypes of rotifers from the Yucatán peninsula according to body length

| Scientific name               | Morph types | Region             | Length   | n     |
|-------------------------------|-------------|--------------------|----------|-------|
| Lecane bulla                  | Small type  | East northwest     | 107.1 ± 3.9| >10   |
| L. bulla                      | Small type  | East southeast     | 102.9 ± 4.5| >10   |
| L. bulla                      | Small type  | East southeast     | 108.1 ± 5.6| >10   |
| L. bulla                      | Small type  | Northeast          | 112.2 ± 7.9| >10   |
| L. bulla                      | Large type  | Northeast          | 125.7 ± 6.9| >10   |
| L. bulla                      | Large type  | Northeast          | 131.4 ± 4.2| >10   |
| L. bulla                      | Large type  | Northeast          | 126.1 ± 2.4| >10   |
| L. bulla                      | Large type  | Northeast          | 125.7 ± 5.5| >10   |
| L. bulla                      | Large type  | Northeast          | 122.4 ± 6.4| >10   |
| L. bulla                      | Large type  | Northeast          | 124.7 ± 4.5| >10   |
| Keratella americana           | Large type  | East northwest     | 104.2 ± 2.5| 9     |
| K. americana                  | Large type  | East northwest     | 106.26 ± 6.62| 2    |
| K. americana                  | Small type  | Northeast          | 89.66 ± 2.84| 4     |
| K. americana                  | Small type  | Northeast          | 90.46 ± 2.67| 9     |
| K. americana                  | Small type  | Northeast          | 93.19 ± 3.26| >10   |
| K. americana                  | Small type  | South              | 86.26 ± 1.37| 5     |
| Keratella americana           | Large type  | East               | 84.44 ± 1.10| 2     |
| K. americana                  | Large type  | Southeast          | 95.36 ± 10.67| 1    |
| Philodina cf rosoela          | Large type  | Southeast          | 434.85 ± 70.67| >10  |
| P. cf rosoela                 | Small type  | Southeast          | 335.01 ± 27.46| 8    |
| Brachionus cf ibericus        | Small type  | East               | 124.31 ± 9.29| >10   |
| B. cf ibericus                | Medium type | East               | 144.51 ± 3.65| >10   |
| B. cf ibericus                | Large type  | Northeast          | 155.51 ± 4.70| >10   |
| B. cf ibericus                | Large type  | Northeast          | 111.26 ± 1.76| >10   |
| B. cf ibericus                | Medium type | Northeast          | 127.62 ± 7.46| >10   |

4. Discussion

The bioregion outlined in this study represents a potential landscape corridor for rotifers that live in connected patches the Yucatán peninsula; thereby, it is a useful tool for conserving biodiversity. In this bioregion there were 45 genera represented by 140 species. These rotifer species account for 47.85% of the diversity in Mexico (303 forms of rotifers described in the literature) (Elias-Gutiérrez & Y Garcia-morales, 2011), and if one considers a global scale, 6.89% of the rotifer diversity is present in the corridor (Segers & De Semt, 2008). Certainly, the diversity of rotifer species in the bioregion is ecologically relevant at a regional and national level. For example, rotifers are considered cosmopolites with a broad distribution and they are well adapted to littoral communities (Sarma et al., 2001), limnetic life and benthonic regions (Cervantes-Martínez, 2005). Their evolutionary success has been
attributed to their asexual and sexual reproduction. The former is fast and exponential and enables the rotifers to quickly respond to almost any signal such as overpopulation, predation or competition (Alvarado-Flores et al., 2017). The latter enables them to grow cysts or resistance eggs, which can withstand desiccation and extreme temperatures. Cysts are characteristically recombinant genotypes, thereby they are genetic reservoirs in aquatic ecosystems (Walsh et al., 2017). The above indicates that the bioregions have a genetic resource, that is, a group that is well distributed by all the aquatic ecosystems of the Yucatan peninsula, which can be used as indicator of water quality, evolution, and even for studies of biological connectivity. Rotifers are essential for the aquatic ecosystems in the Yucatan peninsula.

Initially, the bioregion was designed based on the fact that rotifers live in water bodies; hence, their distribution and presence are conditioned by water. For this reason, an intersection of the buffers of species distribution with those of water bodies was made to obtain the final bioregion, called biological corridor (shown in Figure 1). In the bioregion, there is a noticeable intersection of rotifers and bodies of water in northwest Quintana Roo, mainly due to the presence of exokarstic features (uvalas, poljes and dolines), of which 2887 have been reported within an area of 1145.19 km² (Aguilar et al., 2016). Such features provide suitable habitats for the dispersion and reproduction of rotifers in these areas of the corridor.

The bioregion runs from south-eastern to the northwestern Yucatan peninsula and crosses the Calakmul–Sian Ka’an corridor; in this way, the bioregion connects the Yalahau biosphere reserve with the Sian Ka’an and Calakmul biosphere reserves. As a set, these are part of the Mesoamerican Biological Corridor (CBM, 2002). Consequently, the bioregion is considered peninsular, as it comprises Yucatan, Quintana Roo and Chetumal (Figure 1).

Ecologically, the bioregion is home to 45 different genera; three are emphasized in this study: Brachionus with nine species, one of them marine (B. plicatilis sensu lato, with possible sibling species); Keratella with three species; and, Lecane, the most diverse genus, with 44 species. Owing to the broad distribution of these genera in the bioregion, as is apparent in (Figure 2), their species can indicate biological connectivity in the Yucatan peninsula. For example, A.E. Garcia-Morales and Elias-Gutiérrez (2013) detected genetic evidence of the existence of species complexes in these three genera in south-eastern and northwestern Yucatan peninsula. By deciphering their specific complexity, it may be possible to identify and describe still unidentified species present in the biological corridor. We consider these three genera are excellent indicators of water quality and ecosystem health, concurring with Rico-Martínez et al. (2017). For example, B. plicatilis is economically relevant and of ecotoxicological and evolutionary importance (A.E. Garcia-Morales & Elias-Gutiérrez, 2013; Mills et al., 2017). Also, species of Keratella are widely distributed globally, with 53 taxa in total. Mainly, K. americana is common in water bodies in the American continent. For this reason, the authors put forward this rotifer species as a good indicator of environmental disturbance, for it is virtually found in all aquatic systems. Owing to this feature, it is commonly used as a sentinel organism, because it can accumulate toxins in its lorica and experiences morphological changes induced by contamination (Pérez-Yáñez et al., 2019), it is because of this we deem it an excellent indicator (Segers & De Semt, 2008).

Genus Lecane is one of the most diverse in the bioregion in the Yucatan peninsula with 44 species. Globally, 209 taxa are reported (Segers, 2007), most of which are from tropical and subtropical environments.

Rainfall is an essential variable in the distribution of rotifers. Máradero et al. (2011) observed reduced annual rainfall in the Yucatan peninsula for the period 1953–2007, characterized by spatial and temporal rainfall variability at the coast (Table 3), which decreases from the center to the west in the south of the Yucatan peninsula. According to our models, rotifer distribution is well explained by rainfall; in this sense, rainfall anomalies such as droughts probably affect spatial distribution patterns. For example, Álvarez-Cadena et al. (2007) and Cervantes-Martínez (2005) observed that for freshwater tropical aquatic systems, diversity of zooplankton in the Yucatan peninsula and the physical and chemical parameters of water were not homogeneous over the year. In consequence, such diversity changed according to seasonal variations.

The distribution of rotifers, as suggested in reports by Cervantes-Martínez (2005), is influenced by the hydrogeochemical conditions of water. For example, in north-eastern Quintana Roo, changes have been identified in the chemical composition of water and seemingly have influenced the distribution of rotifer species in this zone. According to our modeling data for species distribution, conductivity is the chemical variable most likely to
influence the distribution of species. Albeit, as indicated by our model, the contribution of conductivity to explain this distribution is moderate for rotifers, only 28.4%. Rainfall and water temperature, among possible influential variables, contribute the most to explain the distribution of Lecane, which is a tropicopolitan genus that has great diversity in the bioregion—44 species. These results are ecologically relevant for the Yucatán peninsula and suggest that Lecane is an ideal species for studies on climate change. There are other essential aspects to consider in the general distribution of rotifers in the Yucatán peninsula. One is the complexity of species in the group, since many taxa possess phenotypical plasticity (Segers, 2008; Snell & Janssen, 1995). Another is the existence of morphotypes, which are still described as subspecies, especially in taxa, for which there are no recent, exhaustive reviews available, as for example, in the case of the Lecanidae family (Segers, 2007).

Prospectively, our results demonstrate that there are generally two morphotypes of rotifers in the Yucatán peninsula, a small one in the south, another large in the north. It is essential to consider that all the aquatic ecosystems studied are located in a karst aquifer, where the physical-chemical variables are considered homogeneous (Schmitter-Soto et al., 2002), except for electrical conductivity that is considered the only variable that affects the chemistry of water in karst aquifers (Pérez et al., 2011). It is also known that electrical conductivity in zooplankton organisms, such as ostracods, influences their body size, for these tend to be larger when values surpass 1000 µS/cm (Macario-González et al., 2018). In the particular case of Lecane bulla, it was observed that the large morphotype was distributed in aquatic ecosystems with values of electrical conductivity in a range from 0.2 to 1.3 mS/cm (200 to 1,300 µS/cm). Moreover, the small morphotype was distributed in aquatic ecosystems with electrical conductivity values between 3.5 and 9.2 mS/cm (3,500 to 9,200 µS/cm). Then, the electrical conductivity is probably the variable that determines the morphotypes and the differences in size between the morphotypes of L. bulla. We attributed this differentiation in the morphology of rotifers to the local adaptation induced by the properties of water in the aquatic ecosystems they inhabit.

The determining factors for the establishment of rotifers in aquatic ecosystems are known to be temperature, electrical conductivity and habitat (Fontaneto, 2019). Rotifers Brachionus plicatilis sensu lato, which present alternative seasonal succession periods, can displace or allow other morphotypes in the same habitat type (Papakostas et al., 2013). It is known that different morphotypes of rotifers can coexist in the same aquatic ecosystem (Gabaldón et al., 2017), and even as mentioned by Ortells et al. (2003) for members of the B. plicatilis species complex, the different patterns of seasonal succession help explain their coexistence.

5. Conclusions
This contribution provides a global vision of the diversity of rotifer species in the Yucatán peninsula. The analysis represents a baseline of the current distribution, making it possible to carry out studies at local and regional scales. We propose this bioregion as a prospective corridor for rotifers. In the entire Yucatán peninsula, the diversity of rotifers is likely to have the same pattern of morphotypes: small ones in the southern zone, large ones in the north. It is also essential to monitor physical and chemical changes in water bodies and bioclimatic variables to integrate a genus-specific distribution model, generate distribution scenarios related to climate change, habitat fragmentation, change in land use, and anthropogenic contamination. It is highly probable there are cryptic and sibling species in this rotifer corridor. However, presently, the impact of activities and pressure on aquatic ecosystems in the Yucatán peninsula is high. In consequence, the possibility of losing species increases.

Public interest statement
The working group of Ecology and Dynamic of Aquatic Ecosystems of the Water Sciences Unit in the Center of Scientific Research of Yucatan is engaged in producing health, water quality and ecologic indicators in collaboration with national and international as well as inter- and intra-institutional research groups to offer important information to relevant water-management agencies, decision-making regarding public policies, species conservation, and genetic resources and as regards water security.

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