First records of freshwater molluscs from the ecological reserve El Edén, Quintana Roo, Mexico

Primeros registros de moluscos dulceacuícolas de la Reserva Ecológica El Edén, Quintana Roo, México.

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Abstract. The diversity of the freshwater molluscs at El Edén was unknown. This is the first treatment of them, allowing us to compare spatial and temporal species distribution. Eleven species of freshwater molluscs were found in 2 surveys carried in March (dry season) and September (rainy season) 1998 at the reserve El Edén. A total of 266 individuals were collected; 8 pulmonates, *Mayabina spiculata*, *Mexinauta impluviatus*, *Physa* sp., *Biomphalaria havanensis*, *Drepanotrema lucidum*, *Drepanotrema kermatoides*, *Planorbella* (*Pierosoma*) *trivolvis*, and *Planorbula armigera*; 2 prosobranchs, *Pyrgophorus* sp. and *Pomacea flagellata*; and one bivalve, *Musculium transversum*. Pulmonata dominate over Prosobranchia species in diversity. No significant differences were observed in diversity between dry and rainy seasons. However, species abundance recorded in both seasons was very low, probably due to a combination of inadequate food resources and disadvantageous climate (periodic conditions of drought and flooding). Further studies using a combination of different sampling methods and more frequent samplings are needed to confirm or identify these factors. We suggest that future studies should focus on cultivation of species with economic potential such as the apple snail *Pomacea flagellata*.

Key words: freshwater snails, bivalves, Yucatan Peninsula, diversity, abundance.

Introduction

A number of surveys on mollusc fauna have been conducted in the Yucatán Peninsula (e.g., Morelet, 1849, 1851; Fischer and Crosse, 1870-1878; Pilsbry, 1891; Martens, 1890-1901, Bequaert and Clench, 1933; Richards, 1937; Harry, 1950; Rehder, 1966). However, very few studies (i.e., Richards, 1937; Rehder, 1966) are
Due to the low number of records and the fact that terrestrial snails are often the primary targets of these surveys, freshwater molluscs in the northeastern part of the peninsula remain poorly studied. This holds true despite the fact that the zone constitutes an important center of endemism within the Yucatan Peninsula (Lazcano-Barrero et al., 1992).

The ecological reserve El Edén was established in 1990. It is the first non-governmental reserve focusing on biological conservation in Mexico and is situated in Quintana Roo at 21° 13’ N and 87° 11’ W (Figure 1). The ecological reserve has an extension of 1492 hectares. The climate is Aw1 (x’) (García, 1981) with an average annual temperature of 24.7 °C and an annual precipitation of 1511.9 mm (Reserva Ecológica El Edén, 1995). Heavy rainfall combined with a series of karstic depressions called the Holbox fracture (Weidie, 1982) contributes to the formation of seasonally flooded wetlands (Morrison, 2000). In this ecosystem, water remains trapped in natural holes or sinkholes. These sinkholes or “solution features” are the result of CO2 enriched rainwater reacting chemically with limestone bedrock to dissolve it (Back, 1985). As a result of these interactions, a patchy network of water crevices is formed.

Perennial sources of water are available in the form of small lakes and ponds in the tropical dry forest and savanna forest. This habitat diversity could promote the coexistence of several freshwater species in the same general area. However, abrupt seasonal changes make an impact on habitat stability (e.g., perennial vs. temporal) and thus may constrain populations spatially or temporally.

Since no previous taxonomic or ecological records exist for this locality, the main aim of this initial survey was to assess the current diversity of freshwater molluscs and compare the species distribution spatially, in various sites within the ecological reserve, and temporally, in the dry and rainy seasons.

**Material and methods**

Surveys were conducted in March and September 1998 as these months correspond to the dry and rainy seasons. After an initial inspection of several water bodies in the ecological reserve, five sampling sites were chosen to evaluate species composition. The sampling sites had different characteristics and were thought to be a small but representative sample of the different aquatic habitats in the ecological reserve (Table 1). The chosen sites were sampled using 0.09 m² quadrats (sample unit). The number of quadrats sampled was weighted against sites’ characteristics, with densely vegetated sites being sampled more intensely than ponds with fewer vegetational associations and substrata. Quadrats were inspected visually for molluscs and substrata and macrophytes within the quadrats were swept with a small sampling net (mesh 1 mm, frame aperture 140 × 100 mm, bag depth 80 mm). Live organisms were treated with a 10% ethanol solution previous to fixation to ensure relaxation of tissues (Green et al., 1981). A 70% ethanol solution was used as final fixative. Empty shells were also collected and cleaned using a soft soap solution and then sonicated for 15 to 20 seconds. Shells were sonicated separately to avoid friction or ruptures. Variations in shell morphology and size ranges, as reported in specialized literature (e.g. Baker, 1945; Burch, 1989; Burch and Cruz Reyes, 1987; Herrington, 1962; Fischer and Crosse, 1870-1900; Pennack, 1989 and Martens, 1890-1901), were used to make identifications. Also, whenever organisms were available, comparisons of the reproductive system were made through dissections. Based on the number of species and relative abundance, the species richness (S), and the Shannon diversity index (H’) were calculated for each sampling site. The Wilcoxon Matched-Pairs Signed Ranks test (Wtest) was used to compare the diversity (H’) values between the dry and rainy seasons in all sample sites.

**Results**

Sampling sites chosen for the study ranged from large perennial ponds to small ephemeral micro- cenotes.
A total of eleven species of freshwater molluscs were found inhabiting the sites at El Edén ecological reserve (Table 2). The dominant group was the subclass Pulmonata (eight species). The subclass Prosobranchia and the class Bivalvia were represented with two and one species, respectively. The balance between prosobranchs and pulmonates was similar to that reported for other parts of the peninsula (Bequaert and Clench, 1933) but the number of species was higher in this study. However, species identification was based almost entirely on shells, as only 10.9% of the total number of individuals collected (n = 256) were living. Seventy four shells/organisms were found in the dry season and 182 shells/organisms were found during the rainy season. The molluscan material collected by one of us (RCC-M) at El Edén Ecological Reserve was deposited at the Colección Nacional de Moluscos CNMO (National Malacological Collection) of Instituto de Biología de la Universidad Nacional Autónoma de México (IBUNAM) (see Table 2).

Species richness: \( a = \text{mean (s.e.)}, b = \text{cumulative} \)

or sinkholes (Table 1). A total of eleven species of freshwater molluscs were found inhabiting the sites at El Edén ecological reserve (Table 2). The dominant group was the subclass Pulmonata (eight species). The subclass Prosobranchia and the class Bivalvia were represented with two and one species, respectively. The balance between prosobranchs and pulmonates was similar to that reported for other parts of the peninsula (Bequaert and Clench, 1933) but the number of species was higher in this study. However, species identification was based almost entirely on shells, as only 10.9% of the total number of individuals collected (n = 256) were living. Seventy four shells/organisms were found in the dry season and 182 shells/organisms were found during the rainy season. The molluscan material collected by one of us (RCC-M) at El Edén Ecological Reserve was deposited at the Colección Nacional de Moluscos CNMO (National Malacological Collection) of Instituto de Biología de la Universidad Nacional Autónoma de México (IBUNAM) (see Table 2). Species richness. Table 1 shows species richness as the mean and the cumulative (maximum) value for each sampling site. Sites 3, 4 and 5 (two perennial and one temporal) had the highest number of species throughout the study (all of them a cumulative number of species equal to 10) whereas sampling site 2 registered only two species. Data in Table 2 show that species richness increased during the rainy season collection in four out of five sites (sites 1, 3, 4 and 5) but the overall abundance only increased in three out five sites (sites 1, 3 and 4) during the rainy season. Four species from the Suborder Pulmonata (two Physidae and two Planorbidae) were only recorded in this latter season. The overall species richness found in this study is low compared to that reported for the Yucatan peninsula.

**Diversity within sites and seasons.** Molluscan diversity did not differ significantly between the two seasons (Wtest, \( p = 0.312, \text{NS} \)) and was generally low in all sampling sites (Table 3). All perennial sites (sites 1, 3 and 5) and one temporal site (site 4) became more diverse in the rainy season whereas site 2 (temporal) became less diverse and just one organism was registered during the rainy season collection.

**Discussion**

This first field survey in the ecological reserve showed little occupancy and a low abundance of freshwater molluscs in the sampling sites. However, due to the lack of previous surveys in the zone, it was not possible to compare the present findings with previous data. As was to be expected, perennial sites seemed to hold consistently higher numbers of species than temporal ones, but, during this study, it was seen that even perennial sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Type</th>
<th>Habitat description and plant associations</th>
<th>Dimension (m²)</th>
<th>Species richness ( a, b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perennial</td>
<td>Deep pond enclosed in Savanna forest. Cyperaceae plants and aquatic plants such as <em>Nymphaea</em> as predominant types. Organic matter and wood debris as substratum types.</td>
<td>100</td>
<td>6 (3.0) 9</td>
</tr>
<tr>
<td>2</td>
<td>Temporal</td>
<td>Shallow depression with a predominantly algal substratum and few patches of <em>Cladium jamaicense</em>.</td>
<td>10</td>
<td>1.5 (0.5) 2</td>
</tr>
<tr>
<td>3</td>
<td>Perennial</td>
<td>Natural pond located between the savanna and the tropical dry forest. Algae and organic matter are the main substratum types and a vegetal composition of trees like <em>Byrsonima crassifolia</em> and sub-aquatic plants like <em>Cladium jamaicense</em> is observed in the periphery of the pond.</td>
<td>33</td>
<td>7.5 (0.5) 10</td>
</tr>
<tr>
<td>4</td>
<td>Temporal</td>
<td>Shallow depression with a rocky substratum with organic matter and some algae</td>
<td>2</td>
<td>6.5 (1.5) 10</td>
</tr>
<tr>
<td>5</td>
<td>Perennial</td>
<td>Shallow pond with at least three vascular plant species (e.g. <em>Paurotis wrightii</em> and <em>C. jamaicense</em>). Organic matter, macrophyte roots and algae as substrata.</td>
<td>22</td>
<td>7.5 (2.5) 10</td>
</tr>
</tbody>
</table>
Cózatl-Manzano and Naranjo-García.- Freshwater molluscs of El Edén

and 1938), who reported a total of 16 species plus 2 subspecies of freshwater molluscs; today these numbers have been reduced to 11 species and 1 subspecies due to taxonomic changes; the number of freshwater molluscan species is variable in other regions of the world (Table 4), perhaps due to the different historical environmental conditions prevailing in each site (such as type of climate and vegetation). Mexico’s freshwater molluscan fauna is incompletely known; however, Contreras-Arquieta (2000) has compiled a total of 310 species and 44 subspecies that have been recorded for the country. Russell-Hunter (1978) noticed that freshwater molluscan genera of the world are relatively low in number.

The current freshwater malacological composition at El Edén could be explained in part by the numerous marine transgressions that kept most of the Yucatan peninsula under seawater at different geological periods, suffer environmental alterations as a consequence of drought (see Cózatl-Manzano, 1999). This could explain the increment in species richness and diversity values observed for the rainy season. Environmental alterations such as prolonged drought could also explain the higher number of pulmonate species relative to prosobranchs as the former group is thought to be better adapted to deal with drought conditions than the latter (Hunter, 1964). Indeed, some of the pulmonate species recorded consistently for both seasons in the ecological reserve (i.e., B. havanensis, P. trivolvis) are known to tolerate harsh environmental conditions (Dazo, 1965; Clarke, 1969). The presence of only prosobranchs such as the amphibious P. flagellata supports the idea that only tolerant species are able to colonize these habitats.

Species richness in the Yucatan Peninsula was considered low by Bequaert and Clench (1933, 1936 and 1938), who reported a total of 16 species plus 2 subspecies of freshwater molluscs; today these numbers have been reduced to 11 species and 1 subspecies due to taxonomic changes; the number of freshwater molluscan species is variable in other regions of the world (Table 4), perhaps due to the different historical environmental conditions prevailing in each site (such as type of climate and vegetation). Mexico’s freshwater molluscan fauna is incompletely known; however, Contreras-Arquieta (2000) has compiled a total of 310 species and 44 subspecies that have been recorded for the country. Russell-Hunter (1978) noticed that freshwater molluscan genera of the world are relatively low in number.

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Table 2. Frequencies and relative abundances of freshwater molluscs for the dry (D) and rainy (R) seasons at El Edén ecological reserve for the five sampling sites (numbers 1 to 5)

<table>
<thead>
<tr>
<th>Taxon</th>
<th>1 D</th>
<th>1 R</th>
<th>2 D</th>
<th>2 R</th>
<th>3 D</th>
<th>3 R</th>
<th>4 D</th>
<th>4 R</th>
<th>5 D</th>
<th>5 R</th>
<th>Number per sp.</th>
<th>Relative Abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayabina spiculata (Morelet, 1849) CNMO 2145</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td></td>
<td>4.30</td>
<td></td>
</tr>
<tr>
<td>Mexinauta impluvius (Morelet, 1849) CNMO 2151</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>6.64</td>
</tr>
<tr>
<td>Physa sp. CNMO 2152</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>18</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>38</td>
<td>14.84</td>
</tr>
<tr>
<td>Biomphalaria havanensis (Pfeiffer, 1839) CNMO 2155</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>46</td>
<td>17.97</td>
</tr>
<tr>
<td>Drepanotrema lucidum (Pfeiffer, 1839) CNMO 2146, CNMO 2153, CNMO 2157</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>14</td>
<td>5.47</td>
</tr>
<tr>
<td>Drepanotrema kermatoides Orbigny D’, 1835 CNMO 2143, CNMO 2156, CNMO 2158</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>14</td>
<td>5.47</td>
<td></td>
</tr>
<tr>
<td>Planorbea (Pierosoma) trivolvis (Say, 1817) CNMO 2144</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>9</td>
<td>3.52</td>
</tr>
<tr>
<td>Planorbutella armigera (Say, 1821) CNMO 2149</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>9</td>
<td>36</td>
<td>14.06</td>
</tr>
<tr>
<td>Pomacea flagellata (Say, 1829) CNMO 2154</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>21</td>
<td>8.20</td>
</tr>
<tr>
<td>Pyrgophorus sp. CNMO 2148, CNMO 2150</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>14</td>
<td>2</td>
<td>37</td>
<td>14.45</td>
</tr>
<tr>
<td>Musculium transversum (Say, 1829) CNMO 2147</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>13</td>
<td>5.08</td>
<td></td>
</tr>
<tr>
<td>Number per season</td>
<td>13</td>
<td>64</td>
<td>3</td>
<td>1</td>
<td>21</td>
<td>68</td>
<td>7</td>
<td>20</td>
<td>30</td>
<td>29</td>
<td>256</td>
<td>100.00</td>
</tr>
</tbody>
</table>
These transgressions might have not allowed for a significant increase in molluscan species diversity and might also explain the lack of endemic groups. Indeed, these transgressions might have restricted the distribution of several other freshwater invertebrate communities in the peninsula (see Suárez-Morales, 2003). Bequaert and Clench (1933) reasoned that several points could explain the relatively low number of freshwater molluscan species: the young age of the Peninsula of Yucatan (geologically speaking), and the low number of freshwater bodies.

Regarding species distribution, *Mayabina spiculata* is located from central Campeche to Yucatan and Quintana Roo (Taylor, 2003), and up to the present time this species has been located only at the Yucatan peninsula. *Mexinauta impluviatus* inhabits from eastern Chiapas to Guatemala (Taylor, 2003). * Biomphalaria havanensis* has a distribution from southern Sonora to Colima, Western Mexico, central and southern Oaxaca and from Tamaulipas to Yucatan on the East (Naranjo-García, 1983), it is also present in Florida, Louisiana and Texas in the US (Burch, 1989), in Cuba and Jamaica, Central America and Venezuela (Yong et al. 1995, 2001), in Guatemala it is recorded from Lake Dueñas, in Belize from a pond at Boston Village, in San Salvador at El Salvador as *Biomphalaria obstricta* (Paraense, 2003). The species *Drepanotrema lucidum* is distributed in Mexico (Harry and Hubendick, 1964), Central America (Paraense, 2003), Central America, the Greater Antilles, some Bahama Islands, and many of the lesser Antilles (Harry and Hubendick, 1964); it also inhabits in Brazil (Paraense, 1975; Thiengo et al.,2004), Peru (Paredes et al., 1999), Uruguay (Scarabino, 2004) and Argentina (Paraense, 2005; Gutiérrez Gregoric et al., 2006). *Drepanotrema kermatoides* inhabits Florida, Texas, Mexico, Central America, Venezuela, Peru, Brazil and Lesser Antilles (Burch, 1989) at Brazil from Rio Grande do Sul and Matto Grosso (Paraense, 1975), it is also found in Peru (Paredes et al., 1999), Uruguay (Scarabino, 2004) and Argentina (Paraense, 2005; Gutiérrez Gregoric et al., 2006). *Planorbula armigera* occurs in New Brunswick, Western to South-Eastern Ontario, West to Saskatchewan, Canada, South Georgia and Louisiana and West to Nebraska in the US (Burch, 1989); this is the second record of the genus in Mexico (Naranjo-García -2004- collected it in north east Mexico at Tamaulipas state). *Planorbella (Pierosoma) trivolvis* is distributed in Canada, the United States (Alaska, the Atlantic coast and the Mississippi River, Tennessee and Missouri) (Burch, 1989), in Mexico at Veracruz and Central America (Nicaragua at Lake Nicaragua; Guatemala at Lake San Cristóbal; Costa Rica from Coris River) (Paraense, 2003); Paredes et al. (1999) have also recorded *P. trivolvis* from Peru (as *Helisoma trivolvis*). *Pomacea flagellata* is distributed from northern Veracruz, Tabasco, Quintana Roo, Chiapas in Mexico, Central America to Colombia (Naranjo-García and García-Cubas, 1986). The genus *Pyrgophorus* is widely distributed in the Antilles, North America Central America and South America (Hershler and Thompson, 1992). *Musculium transversum* is found from Canada, the US (Burch, 1975), north of Mexico (Sonora and Tamaulipas) to Tabasco (Bequaert and Miller, 1973).

Data from the Shannon diversity index (H’) obtained in this study offered little information. Mason (1977) and Hughes (1978) recognize that factors such as an infrequent sampling program or the use of a single sampling method could potentially bias results when conducting field surveys. In this case, the small number of ponds surveyed, but moreover, the small number of organisms found alive in this first study, make it difficult to get a clear view of the

<table>
<thead>
<tr>
<th>Site</th>
<th>(H’) dry season</th>
<th>(H’) rainy season</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.57</td>
<td>3.02</td>
</tr>
<tr>
<td>2</td>
<td>0.92</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2.58</td>
<td>2.74</td>
</tr>
<tr>
<td>4</td>
<td>2.24</td>
<td>2.85</td>
</tr>
<tr>
<td>5</td>
<td>1.82</td>
<td>2.87</td>
</tr>
</tbody>
</table>

### Table 4. Number of freshwater molluscs found, location and reference

<table>
<thead>
<tr>
<th>Number of freshwater molluscan species</th>
<th>Location</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>354</td>
<td>Mexico</td>
<td>Contreras-Arquíeta, 2000</td>
</tr>
<tr>
<td>500</td>
<td>USA</td>
<td>Burch, 1989</td>
</tr>
<tr>
<td>73</td>
<td>Chile</td>
<td>Zarges, 2006</td>
</tr>
<tr>
<td>34</td>
<td>Arizona, USA</td>
<td>Bequaert and Miller, 1973</td>
</tr>
<tr>
<td>39</td>
<td>Los Tuxtlas, Mexico</td>
<td>Naranjo-García and Polaco, 1997</td>
</tr>
<tr>
<td>18</td>
<td>Salzburg, Austria</td>
<td>Patzner et al., 1996</td>
</tr>
</tbody>
</table>
possible effects of environmental changes in molluscan diversity. Particularly, we believe that results from the seasonal analysis should be interpreted cautiously as there was no effective way to establish if a shell found in the dry season had belonged to an organism still alive in the previous season.

Nevertheless, there are still some important results derived from this first survey. For example, it was found that animals of certain species are below the average size reported at other localities in the Yucatan Peninsula (Cózatl-Manzano, 1999). It is possible that the quality of resources available in the ecological reserve, the nature of the landscape (e.g., absence of rivers, few perennial lakes and soils with little organic matter) and the prolonged desiccation periods might be limiting development of some of these groups. At the ecological reserve, a scenario in which certain taxa benefit more than others from particular conditions and are thus able to dominate particular microhabitats seems feasible. In contrast, populations of other species currently at the reserve may exist very close to their population threshold; for example, pulmonate taxa feeding on algae and other sessile components on the periphyton of the ecological reserve. Indeed, analysis of the periphyton composition in the ecological reserve suggests that it might not be a dietary option for some of the herbivores, as it is constituted mainly of cyanophytic algae (Novelo and Tavera, 2003) a very 'heavy' (toxic in some cases) diet (Novelo and Tavera, personal communication). Further studies are needed to establish whether or not the quality of the available resources might be undermining the reproductive and growth potential of some species. Such studies could be of use, particularly if applied to economically important (edible) species in the reserve like the apple snail *Pomacea flargellata* (Lobo-Vargas, 1986). For future surveys we recommend longer, and more frequent sampling efforts combining visual inspections and net sweeping with other sampling techniques such as the use of Surber or cylinder samplers.

**Acknowledgments**

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