



## 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.

Roberto Cózatl-Manzano<sup>1</sup> y Edna Naranjo-García<sup>2\*</sup>

<sup>1</sup>UK Data Archive, University of Essex, Colchester CO4 3SQ, U.K.

<sup>2</sup>Departamento de Zoología, Instituto de Biología, Universidad Nacional Autónoma de México, Apartado postal 70-153, 04510 México D. F., Mexico.

\*Correspondent: naranjo@servidor.unam.mx

**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.

**Resumen.** La diversidad de moluscos dulceacuícolas de la Reserva Ecológica El Edén se desconocía; este estudio constituye su primer registro. Asimismo, esta investigación permite comparar la distribución espacial y temporal de las especies registradas. Las recolectas se efectuaron en marzo (temporada de sequía) y septiembre (lluvia) de 1998. Se registran 11 especies (266 individuos en total), 8 pulmonados: *Mayabina spiculata*, *Mexinauta impluviatus*, *Physa* sp., *Biomphalaria havanensis*, *Drepanotrema lucidum*, *Drepanotrema kermatoides*, *Planorbella (Pierosoma) trivolvis* y *Planorbula armigera*; dos prosobranquios: *Pyrgophorus* sp. y *Pomacea flagellata*, y un bivalvo: *Musculium transversum*. Los pulmonados son dominantes sobre los prosobranquios en diversidad; además, la diversidad de especies en la región es superior a la registrada en publicaciones anteriores. No hubo diferencias significativas entre los valores de diversidad de las temporadas de sequía y lluvia. La abundancia en ambas temporadas fue muy baja, posiblemente debido a una combinación de factores negativos, como recursos alimenticios inadecuados y condiciones climáticas desfavorables (períodos continuos de sequía e inundación). Para confirmar o identificar los factores que controlan estas poblaciones en El Edén, será necesario realizar estudios más detallados utilizando métodos de muestreo combinados y cuyo esfuerzo de muestreo sea mayor. Se sugiere que investigaciones futuras podrían enfocarse al establecimiento de cultivos de especies con potencial económico como por ejemplo, del caracol manzana *Pomacea flagellata*.

**Palabras clave:** caracoles, bivalvos, dulceacuícolas, península de Yucatán, diversidad, abundancia.

## 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

specific to the Quintana Roo fauna.

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 CO<sub>2</sub> 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 m<sup>2</sup> quadrats (sample unit). The number of quadrats sampled was weighted against sites'



**Figure 1.** Location of the ecological reserve El Edén in the Yucatán Peninsula, shown with a black dot.

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*

**Table 1.** Description and species richness values for five sampling sites at El Edén ecological reserve

Site	Type	Habitat description and plant associations	Dimension (m <sup>2</sup> )	Species richness a b
1	Perennial	Deep pond enclosed in Savanna forest. Cyperaceae plants and aquatic plants such as <i>Nymphaea</i> as predominant types. Organic matter and wood debris as substratum types	100	6 (3.0) 9
2	Temporal	Shallow depression with a predominantly algal substratum and few patches of <i>Cladium jamaicense</i> .	10	1.5 (0.5) 2
3	Perennial	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 <i>Byrsonima crassifolia</i> and sub-aquatic plants like <i>Cladium jamaicense</i> is observed in the periphery of the pond	33	7.5 (0.5) 10
4	Temporal	Shallow depression with a rocky substratum with organic matter and some algae	2	6.5 (1.5) 10
5	Perennial	Shallow pond with at least three vascular plant species (e.g. <i>Paurotis wrightii</i> and <i>C. jamaicense</i> ). Organic matter, macrophyte roots and algae as substrata	22	7.5 (2.5) 10

Species richness: a = mean (s.e.), b = 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,  $p = 0.312$ , 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 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)

Sampling sites Taxon	Season	1		2		3		4		5		Number per sp.	Relative Abundance (%)
		D	R	D	R	D	R	D	R	D	R		
<i>Mayabina spiculata</i> (Morelet, 1849) CNMO 2145		0	10	0	0	1	0	0	0	0	0	11	4.30
<i>Mexinauta impluviatus</i> (Morelet, 1849) CNMO 2151		0	7	0	0	5	0	0	2	2	1	17	6.64
<i>Physa</i> sp. CNMO 2152		0	10	0	0	2	18	1	4	0	3	38	14.84
<i>Biomphalaria havanensis</i> (Pfeiffer, 1839) CNMO 2155		4	8	1	0	5	10	1	1	10	6	46	17.97
<i>Drepanotrema lucidum</i> (Pfeiffer, 1839) CNMO 2146, CNMO 2153, CNMO 2157		0	6	0	0	0	4	0	3	0	1	14	5.47
<i>Drepanotrema kermatoides</i> Orbigny D', 1835 CNMO 2143, CNMO 2156, CNMO 2158		0	0	0	0	0	9	0	2	2	1	14	5.47
<i>Planorbella</i> ( <i>Pierosoma</i> ) <i>trivolvís</i> (Say, 1817) CNMO 2144		4	1	0	0	1	1	1	0	0	1	9	3.52
<i>Planorbula armigera</i> (Say, 1821) CNMO 2149		0	9	0	0	0	15	0	3	0	9	36	14.06
<i>Pomacea flagellata</i> (Say, 1829) CNMO 2154		5	4	2	1	4	1	2	0	0	2	21	8.20
<i>Pyrgophorus</i> sp. CNMO 2148, CNMO 2150		0	9	0	0	3	3	2	4	14	2	37	14.45
<i>Musculium transversum</i> (Say, 1829) CNMO 2147		0	0	0	0	0	7	0	1	2	3	13	5.08
Number per season		13	64	3	1	21	68	7	20	30	29	256	100.00

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. trivolvís*) 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.

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,

**Table 3.** Values for the Shannon diversity index at the five sites studied over the two sampling seasons

Site	(H') dry season	(H') rainy season
1	1.57	3.02
2	0.92	0
3	2.58	2.74
4	2.24	2.85
5	1.82	2.87

and as late as post-Pliocene times (Richards, 1937). 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 obstructa* (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

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

Number of freshwater molluscan species	Location	Source
354	Mexico	Contreras-Arquieta, 2000
500	USA	Burch, 1989
73	Chile	Zarges, 2006
34	Arizona, USA	Bequaert and Miller, 1973
39	Los Tuxtlas, Mexico	Naranjo-García and Polaco, 1997
18	Salzburg, Austria	Patzner et al., 1996

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

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 flagellata* (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

We are grateful to Arturo Gómez-Pompa, Francisco Vega-Vera and all members from El Edén ecological reserve for the facilities and guidance provided for this study. This work was funded by PROBETEL of the UNAM foundation, through a scholarship awarded to R.C.M. To Fernando Chiang-Cabrera, who made several comments that improved the manuscript.

### Literature cited

- Back, W. 1985. Hydrogeology of Yucatan, p. 99-102. In *Geology and Hydrogeology of the Yucatan and Quaternary Geology of Northeastern Yucatan Peninsula*, W. C. Ward, A.E. Weidie and W. Back (eds.). New Orleans Geological Society, New Orleans. 160 p.
- Baker, F.C. 1945. The molluscan family Planorbidae. University of Illinois Press, Urbana, Illinois. 530 p.
- Bequaert, J. C. and J. Clench. 1933. The non-marine Molluscs of Yucatan. Carnegie Institution Washington Publication 431:525-545.
- Bequaert, J. C. and J. Clench. 1936. A second contribution to the molluscan fauna of Yucatan. Carnegie Institution Washington Publication 457:61-75.
- Bequaert, J. C. and J. Clench. 1938. A third contribution to the molluscan fauna of Yucatan. Carnegie Institution Washington Publication 491:257-260.
- Bequaert, J. C. and W. B. Miller. 1973. The mollusks of the arid southwest. With an Arizona Check list. The University of Arizona Press, Tucson. i-xvi + 271 p.
- Burch, J. B. 1975. Freshwater Sphaeriacean clams (Mollusca: Pelecypoda) of North America. Malacological Publications, Hamburg, Michigan. I-XI + 96 p.
- Burch, J. B. 1989. Freshwater North American Snails. Malacological Publications, Hamburg, Michigan. 365 p.
- Burch, J. B. and A. Cruz-Reyes. 1987. Clave Genérica para la identificación de Gasterópodos de agua dulce en México. Instituto de Biología, UNAM. 46 p.
- Clarke, A. H. 1969. Some aspects of adaptive radiation in recent freshwater molluscs. *Malacologia* 9:263-270.
- Contreras-Arquieta, A. 2000. Bibliografía y lista taxonómica de las especies de moluscos dulceacuícolas en México. *Mexicoa* 2:40-53.
- Cózatl-Manzano, R. 1999. Sistemática de los moluscos dulceacuícolas en la reserva ecológica "El Edén" Quintana Roo, México. Tesis. Facultad de Ciencias, UNAM. 59 p.
- Dazo, B. Z. 1965. The morphology and natural history of *Pleurocera acuta* and *Goniobasis livescens*. *Malacologia* 2:1-80.
- Fischer, M. P. and H. Crosse. 1870-1878. Etudes sur les mollusques terrestres et fluviatiles du Mexique et dans L'Amerique Centrale. *Recherches Zoologiques*. Séptime parte. Paris. 702 p.
- García, E. 1981. Modificaciones al sistema de Clasificación Climática de Köppen. Offset Larios S. A. México D.F. 252 p.
- Green, J., J. E. Morton, D. Nichols and D. Wakelin. 1981.

- Practical Invertebrate Zoology. Blackwell Sci. Pub. New York. 356 p.
- Gutiérrez Gregoric, D.E., V. Núñez, A. Rumi and M.A. Roche. 2006. Freshwater gastropods from Del Plata Basin, Argentina. Checklist and new locality records. Comunicaciones de la Sociedad Malacológica del Uruguay 9:51-60.
- Harry, H. W. 1950. Studies on the non- marine Mollusca of Yucatan. Occasional Papers of the Museum of Zoology, University of Michigan 524:1-34.
- Harry H. W. and B. Hubendick. 1964. The freshwater pulmonate Mollusca of Puerto Rico. Meddelanden Goteborgs Musei Zoologiska Avdelning 136, Ser.B, 9:1-77.
- Herrington, H.B. 1962. A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). Miscellaneous Publications, University of Michigan 118:75 p.
- Hershler, R. and F. G. Thompson. 1992. A review of the aquatic gastropod subfamily Cochliopinae (Prosobranchia: Hydrobiidae). Malacological Review (Suppl. 5). 140 p.
- Hughes, B. D. 1978. The influence of factors other than pollution on the value of Shannon's diversity index for benthic macroinvertebrates in streams. Water Research 12:357-364.
- Hunter, R.W. 1964. Physiological Aspects of Ecology in Nonmarine Molluscs. p. 83-126. In Physiology of Mollusca, Vol. 1, K.M. Wilbur and C.M. Yonge (eds.). Academic Press, New York, New York. 473 p.
- Lazcano - Barrero M.A., I. J. March, H. Núñez, E. Ruelas, A. Muñoz-Alonso and R. Martínez. 1992. Inventario faunístico de la Reserva El Edén, Quintana Roo: Una Prospección. Reporte Técnico. ECOSFERA A. C., San Cristóbal de las Casas, México 54 p.
- Lobo-Vargas, X. 1986. Estudio de algunos aspectos de la biología del molusco *Pomacea flagellata* (Say) (Prosobranchia, Ampullariidae). Tesis. Universidad de Costa Rica. 54 p.
- Mason, C. F. 1977. The performance of a diversity index in describing the zoobenthos of two lakes. Journal of Applied Ecology 14:363-367.
- Morelet, A. 1849 and 1851. Testacea novissima insulae Cubanae et America Centralis (parts I and II) 31, 30 p.
- Morrison, B. 2000. Ancient Maya Settlements of the Yalahau region: An example from the El Eden Wetland. Ph.D. Thesis, University of California, Riverside. 210 p.
- Martens, E. von 1890-1901. Land and Freshwater Mollusca. Biologia Centrali Americana. Zoología 9:1-706.
- Naranjo-García E. 1983. Nuevo registro y consideraciones morfológicas de *Biomphalaria obstructa* (Morelet, 1849) (Mollusca: Gastropoda) en México. Anales del Instituto de Biología, Universidad Nacional Autónoma de México 53 (1982), Serie Zoología:39-47.
- Naranjo-García E. 2004. Notes on the knowledge of the freshwater mollusks of Mexico. Annual Meeting of the Western Society of Malacologists. Ensenada, Baja California, México. Abstracts: 67.
- Naranjo-García E. and A. García-Cubas. 1986. Algunas consideraciones sobre el género *Pomacea* (Gastropoda: Pilidae) en México y Centroamérica. Anales del Instituto de Biología, Universidad Nacional Autónoma de México 56 (1985), Serie Zoología: 603-606.
- Naranjo-García, E. and O. J. Polaco. 1997. Moluscos continentales. In Historia natural de Los Tuxtlas, Veracruz, González-Soriano, E., Dirzo, R. and R. Vogt (eds.). Instituto de Biología, Instituto de Ecología and CONABIO. 647p.
- Novelo, E. and R. Tavera. 2003. The role of periphyton in the regulation and supply of nutrients in a wetland at El Edén, Quintana Roo. P. 217-239. In The lowland Maya Area. Three Millennia at the Human-Wildland Interface, A. Gómez-Pompa, M.F. Allen, S.L. Fedick and J. J. Jiménez-Osornio (eds.). The Haworth Press, Binghamton, New York. 659 p.
- Paraense, W. L. 1975. Estado atual da sistemática dos planorbídeos brasileiros (Mollusca, Gastropoda). Arquivos do Museu Nacional, Rio de Janeiro 55:105-128.
- Paraense, W. L. 2003. A bird's eye survey of Central American Planorbid Molluscs. Memórias del Instituto Oswaldo Cruz, Rio de Janeiro 98:51-67.
- Paraense, W. L. 2005. Planorbidae, Lymnaeidae and Physidae of Argentina (Mollusca: Basommatophora). Memórias del Instituto Oswaldo Cruz, Rio de Janeiro 100:491-493.
- Paredes, C., P. Huamán, F. Cardoso, R. Vivar and V. Vera. 1999. Estado actual del conocimiento de los moluscos acuáticos en el Perú. Revista Peruana de Biología 6:1-17.
- Patzner, R. A., S. Ellmauthaler and U. Rathmayr. 1996. The aquatic molluscs in the Samer Mosl (City of Salzburg). A contribution to the aquatic molluscs in the country of Salzburg. Linzer Biologische Beitrage 28:197-210.
- Pennak, R.W. 1989. Freshwater invertebrates of the United States: Protozoa to Mollusca. John Wiley, New York. 628 p.
- Pilsbry, H. A. 1891. Land and Freshwater molluscs collected in Yucatan and Mexico. Proceedings of the Academy of Natural Sciences of Philadelphia. p. 310-333.
- Rehder, H. A. 1966. The non-marine molluscs of Quintana Roo, Mexico. Proceedings of the Biological Society of

- Washington 79:273-296.
- Reserva Ecológica "El Edén". 1995. Participación del sector privado en la conservación y el desarrollo sustentable. Reporte Técnico, Quintana Roo, México. 13 p.
- Richards, H. G. 1937. Land and freshwater molluscs from the island of Cozumel, Mexico, and their bearing on the geological history of the region. *Proceedings of the American Philosophical Society* 77:249-262.
- Russell-Hunter, W. D. 1978. Ecology of freshwater pulmonates. In *Pulmonates*, Vol. 2A, V. Fretter and J. Peake (eds.). Academic Press, London. 540 p.
- Scarabino, F. 2004. Lista sistemática de los Gastropoda dulciacuícolas vivientes de Uruguay. *Comunicaciones de la Sociedad Malacológica del Uruguay* 8:347-356.
- Suárez-Morales, E. 2003. Historical biogeography and distribution of the freshwater calanoid copepods (Crustacea: Copepoda) of the Yucatan Peninsula, Mexico. *Journal of Biogeography* 30:1851-1859.
- Taylor, D. W. 2003. Introduction to Physidae (Gastropoda: Hygrophila): biogeography, classification, morphology. *Revista de Biología Tropical* 51 (suppl.1): I-XIII + 299p.
- Thiengo, S. C., A. C. Mattos, M. F. Boaventura, M. S. Loureiro, S. B. Santos, M. A. Fernandez. 2004. Freshwater snails and schistosomiasis mansonii in the State of Rio de Janeiro, Brazil: V -Norte Fluminense Mesoregion. *Memorias del Instituto Oswaldo Cruz, Rio de Janeiro*, 99(Suppl. 1):99-103.
- Weidie, A. E. 1982. Lineaments of the Yucatan Peninsula and Fractures of the central Quintana Roo Coast. *Geological Society of America, Annual Meeting* 10: 21-25.
- Yong, M., G. Perera and A. Gutierrez. 1995. *Biomphalaria havanensis* y *Biomphalaria orbigny* (Pulmonata: Planorbidae). ¿Dos especies en sinonimia? Instituto de Medicina Tropical "Pedro Kouri", Comunicación Breve. p. 209-210.
- Yong, M., A. Gutierrez, G. Perera, P. Durand and J.P. Pointier. 2001. The *Biomphalaria havanensis* complex (Gastropoda: Planorbidae) in Cuba: a morphological and genetic study. *Journal of Molluscan Studies* 67:103-111.
- Zarges, C. V. 2006. Estado del conocimiento de los gastropodos dulceacuícolas de Chile. *Gayana* 70:88-95.