

Taxonomy and systematics

The Sabinas River basin in Coahuila, a new hotspot of molluscan biodiversity near Cuatro Ciénegas, Chihuahuan Desert, northern Mexico

La cuenca del río Sabinas en Coahuila, un nuevo “hotspot” de biodiversidad de moluscos cerca de Cuatro Ciénegas, Desierto Chihuahuense, norte de México

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Abstract

The malacofauna of the Sabinas River basin, Coahuila, North Mexico, was studied at 9 sites. In total, 21 native and 2 invasive species were found. Nineteen species were gastropods and 4 species were bivalves. One genus and 2 species of subterranean gastropods are endemic to the area. We report for the first time, a member of the family Amnicolidae in Mexico, *Lyogyrus* sp. *Mexithauma* cf. *quadripaludium* Taylor, 1966 and *Juturnia coahuilae* (Taylor, 1966) (Cochliopidae), previously known only as endemic in the neighboring Cuatro Ciénegas basin, were found for the first time outside of this basin. Also, *Cincinnatia integra* (Say, 1821) (Hydrobiidae), previously known in Mexico only from 1 relict site in San Luis Potosí state, was found living in Sabinas River. In all studied sites, the invasive species *Melanoides tuberculata* (O. F. Müller, 1774) (Thiaridae) and *Corbicula fluminea* (O. F. Müller, 1774) (Cyrenidae) dominate the aquatic molluscan communities. Both molluscs are potential risks for native species, especially if the water pollution continues. At least 10 species from Sabinas River System are of special conservation significance (7 imperiled and 3 vulnerable), due to their endemism, extremely reduced habitat, or relict occurrence in Mexico.

Keywords: Diversity; Freshwater; Gastropods; Bivalves; Conservation

Resumen

La malacofauna de 9 sitios a lo largo de la cuenca río Sabinas, Coahuila, México, fue investigada con base en características conchiliológicas. En total, se encontraron 23 especies de moluscos dulceacuícolas, de las cuales 21 son nativas y 2 invasoras. Diecinueve especies son gasterópodos y 4 son bivalvos. Un género y 2 especies de gasterópodos intersticiales son endémicos del área y se reporta por primera vez a un miembro de la familia Amnicolidae en México, *Lyogyrus* sp. *Mexithauma* cf. *quadripaludium* Taylor, 1966, y *Juturnia coahuilae* (Taylor, 1966) (Cochliopidae), localizados únicamente en el valle de Cuatro Ciénegas, fueron encontrados por primera vez fuera del mismo. Además, también *Cincinnatia integra* (Say, 1821) (Hydrobiidae), conocida en México hasta la fecha solamente como relicto de un solo sitio en San Luis Potosí, fue encontrada viva en el río Sabinas. Las especies invasoras *Melanoides tuberculata* (O. F. Müller, 1774) (Thiaridae) y *Corbicula fluminea* (O. F. Müller, 1774) (Cyrenidae) dominan a las comunidades acuáticas de moluscos en todos los sitios estudiados. Estos dos moluscos forman un riesgo potencial para las especies nativas, especialmente si la contaminación del agua causada por actividades antropogénicas continúa. Por lo menos 10 especies del sistema río Sabinas son de especial importancia para la conservación (7 amenazadas y 3 vulnerables) debido a su endemismo, al hábitat reducido o a su presencia como relicto en México.

Palabras clave: Diversidad; Dulceacuícola; Gasterópodos; Bivalvos; Conservación

Introduction

Freshwater molluscs are some of the most threatened species worldwide and their habitats are highly impacted by several human activities such as dam construction, water pollution, overexploitation of aquifers and habitat degradation (Dudgeon, 2020; Modesto et al., 2017). The decline of freshwater species diversity is a worldwide phenomenon but it is especially pronounced in arid regions such as in the Chihuahuan Desert of Coahuila and Durango, Northern Mexico (Czaja, Covich et al., 2019). The Sabinas River (Fig. 1) is probably one of the least investigated areas in the southeastern part of the Chihuahuan Desert and until now, only 3 species of gastropods have been reported from this region (Contreras-Arquieta, 1998; Czaja, Cardoza-Martínez et al., 2019).

Recently, the Sabinas River basin and the southern adjacent Cuatro Ciénegas Valley have been defined together as 1 (of 3) hotspots of molluscan biodiversity in Mexico (hotspot B *sensu* Czaja et al. [2020]). While the Cuatro Ciénegas basin is a complex of more than 700 springs, small lakes and marshes, the Sabinas basin is composed of 2 large rivers as typical habitat. The valley of Cuatro Ciénegas is one of the most extensively studied locations in North America in relation to molluscs and was identified as a separate freshwater ecoregion and as one of 25 worldwide hotspots of gastropod diversity by Strong et al. (2008). All 7 Mexican freshwater species listed as endangered by the Secretaría de Medio Ambiente y Recursos Naturales (Mexican Secretariat of Environment and Natural Resources) (Semarnat, 2010) occur there.

The aim of the present study is to describe the diversity and conservation status of the molluscs collected at 9 sites (8 sites at Sabinas River and 1 site at Álamos River, Fig. 1)

along the Sabinas River, Don Martín Basin, Coahuila. The area of study is part of the Natural Resources Protection Area, Upper Basin of the National Irrigation District 004 Don Martín, administered by the National Commission of Natural Protected Areas (Conanp). We provide important data that will serve as a basis for further development of conservation strategies of aquatic habitats of this area.

Materials and methods

The freshwater molluscs treated herein were collected in July and November 2018, and May 2019 in 9 sites along the Sabinas and Álamos Rivers (Figs. 1, 2A-F; Table 1). Two fine sand and gravel sediment samples of 2.5 kg each were taken from river shores, which were later screened through 2 sieves with mesh sizes of 0.2 mm and 0.5 mm. The sampling of molluscs was restricted to shallow water less than 1 m deep. The geographic coordinates were taken with a Garmin Etrex 10 GPS (accuracy: 4-10 m).

We agree with the conclusions of Vinarski (2018) regarding the problem of species delimitation in freshwater malacology and the need for an integrative approach. With the exception of *Physella*, *Biomphalaria*, *Melanoides*, *Cincinnatia* and *Corbicula*, all other molluscs were collected as empty shells so we used the morphological species concept in this study. Therefore, shells of all species were photographed and described in detail. All shells were found to have recently died and many still retained operculae, so that we consider these shells represent their biocoenosis. Almost all extant subterranean snails were (and are) described only from empty shells because in many cases living populations were not accessible or available (Georgiev, 2013; Glöer et al., 2015; Grego et al., 2017). Of all species presented here, only members of

the genus *Galba* Schrank, 1803 (Lymnaeidae) could not be identified at the species level due to shell convergence and the presence of many cryptic forms in this group (Alda et al., 2019). Only 1 dusksnail (*Lyogyrus*) specimen was found, so we refrain from describing a new species until further records are made. All other gastropods (except *Mexithauma* cf. *quadripaludium*) were found with sufficient specimens and their shells exhibited features that allow for a distinction on species level, although this often required scanning electron microscope images.

The taxonomy of the snails was based on the classification of Bouchet and Rocroi (2005) and biodiversity website MolluscaBase (MolluscaBase, 2019). For bivalves, we used the classification of Bieler et al. (2010). For morphological analysis, the shells and opercula were photographed and measured with a Zeiss AxioCamERc 5s camera attached to a Zeiss Stemi 2000-C microscope. Some specimens, especially their protoconchs as an essential diagnostic feature (Hershler, 1994; Perez & Minton, 2008), were examined in the Laboratorio de Biotecnología, Universidad Autónoma de Coahuila (UAC) in Torreón, Coahuila, using a HITACHI high performance FlexSEM 1000 scanning electron microscope.

To determine the status of conservation of the 23 species from Sabinas River, we used the NatureServe National Conservation Rank System described by Master et al. (2012). Many of the reported gastropods from the Sabinas River also occur in other sites in Mexico and their status of conservation has recently been assessed by Czaja et al. (2020), where the method is described in detail. Despite the new records presented here, only 1 of the previously reported Mexican species changed its status (*Cochliopina riograndensis*). The scale of the status used by NatureServe Conservation Rank System ranges from critically imperiled (N1) to secure (N5). The studied material is deposited at the Malacological Collection of the Facultad de Ciencias Biológicas de la (UJMC) of the Universidad Juárez del Estado de Durango.

Abbreviations used: UJMC = University Juárez Malacological Collection; NatureServe-Rank-Conservation status: N1 = Critically imperiled, N2 = Imperiled, N3 = Vulnerable, N4 = Apparently secure, N5 = Secure, NH = Possibly extirpated, NX = Presumed extirpated, NU = Unable to assign rank, NQ = Questionable taxonomy. E = endemic, ECC endemic to Cuatro Ciénegas; Morphological terms: A1 = anterior lateral internal tooth, A2 = anterior

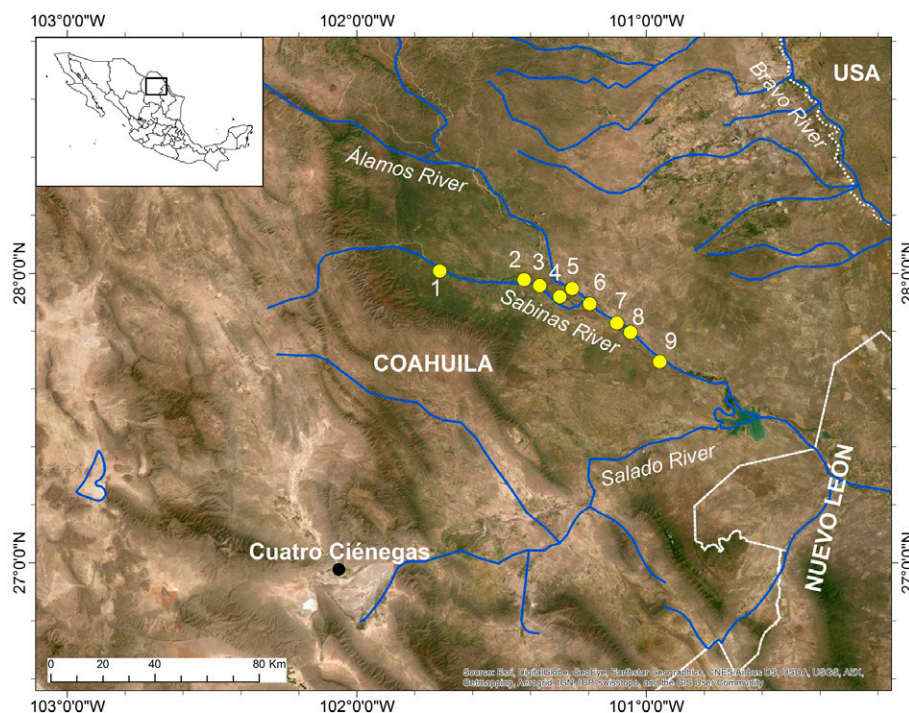


Figure 1. Location of the Sabinas River basin with sampling sites. 1. Sabinas River, Ejido Nacimiento de los Mascogos II, 2. Sabinas River, Ejido Santa María, 3. Sabinas River, Ejido Saucedo del Naranjo, 4. Sabinas River, Ejido San Juan de Sabinas, 5. Álamos River, Ejido Paso del Coyote, 6. Sabinas River, Las Adjuntas (Rancho San Carlos), 7. Sabinas River, Sabinas (Agua Prieta), 8. Sabinas River, Las Cazuelas, 9. Sabinas River, La Vega.

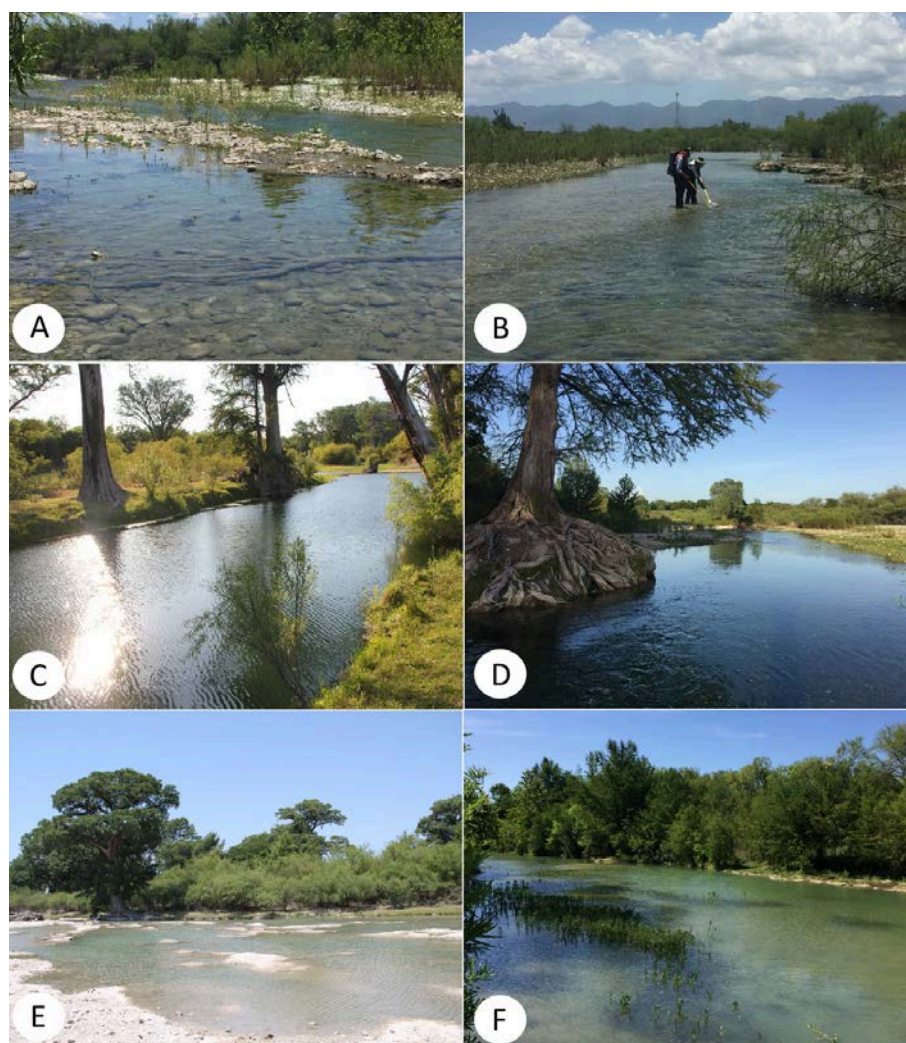


Figure 2. Photographs of typical aquatic habitats along the Sabinas River, Coahuila, Mexico. A, B, Ejido El Nacimiento de los Mascogos II (site 1). C, Las Adjuntas, Rancho San Carlos (site 6). D, Ejido Saucedá del Naranjo (site 3). E, Ejido Guadalupe Victoria. F, Ejido San Juan de Sabinas (site 4).

lateral tooth, A3 = anterior lateral external tooth, C2 (a, b) = internal cardinal tooth, C3 = cardinal tooth, C4 = external cardinal tooth, P1 = posterior lateral internal tooth, P2 = posterior lateral tooth, P3 = posterior lateral external tooth.

Results

Class Bivalvia
 Order Venerida
 Superfamily Cyrenoidea Gray, 1840
 Family Cyrenidae Gray, 1840
 Genus *Corbicula* Megerle von Mühlfeld, 1811
 Type species: *Tellina fluminalis* O. F. Müller, 1774

Corbicula fluminea (O. F. Müller, 1774) (invasive species) (Fig. 3A)

Taxonomic summary

Description. The shell is oval to triangular in adult specimens, heavy, with concentric sulcations; hinge plate with 3 cardinal teeth (C2a, C2b, C4, Fig. 3A); lateral teeth straight to slightly curved and serrated; left valve has 2 long and thin lateral teeth, serrated on both sides (Fig. 3A); right valve with 2 pair of long lateral teeth, inner laterals more prominently serrated on medial surfaces than outer laterals.

Material examined: > 150 specimens (UJMC 450).

Table 1

Sampling sites in the Sabinas and Álamos River with coordinates.

Locality	Coordinates	
1. Sabinas River, Ejido Nacimiento de los Mascogos II	28°00'25'' N	101°42'46'' W
2. Sabinas River, Ejido Santa María	27°58'37'' N	101°25'16'' W
3. Sabinas River, Ejido Saucedo del Naranjo	27°57'24'' N	101°22'04'' W
4. Sabinas River, Ejido San Juan de Sabinas	27°55'06'' N	101°17'54'' W
5. Álamos River, Ejido Paso del Coyote	27°56'45'' N	101°15'19'' W
6. Sabinas River, Las Adjuntas (Rancho San Carlos)	27°53'33'' N	101°11'41'' W
7. Sabinas River, Sabinas (Agua Prieta)	27°49'38'' N	101°06'06'' W
8. Sabinas River, Las Cazuelas	24°47'42'' N	101°03'14'' W
9. Sabinas River, La Vega	27°41'35'' N	100°57'10'' W

Conservation status: N5.

Remarks. Unlike other bivalves from Sabinas River, *C. fluminea* occurs in many types of substrates such as mud, sand and gravel, albeit with different abundances (but prefers seemingly coarse sands and gravel substrate at the base of cobbles). Although the species is known from many sites in Coahuila (López-Altarriba et al., 2019), this is the first record of *C. fluminea* in the Sabinas River.

Order Sphaeriida Lemer, Bieler & Giribet, 2019
 Superfamily Sphaerioidea Deshayes, 1855 (Rafinesque, 1820)
 Family Sphaeriidae Deshayes, 1855 (Rafinesque, 1820)
 Genus *Pisidium* C. Pfeiffer, 1821
 Type species: *Tellina amnica* Müller, 1774 by subsequent designation (Gray, 1847)
Pisidium nitidum Jenyns, 1832
 (Fig. 3B, C)

Taxonomic summary

Description. Shell oval in shape, all hinge teeth well developed, C3 slightly curved (Fig. 3C) and somewhat enlarged at posterior end, parallel with hinge, C2 and C4 fairly straight and near parallel, subequal in length, C2 longer (Fig. 3B), C4 thin; lateral teeth A1 and A2 large, P1 thin and straight, P3 and A3 shorter. The characteristic “*peculiar striae...across the umbones*”, stressed in the original description of Jenyns (1832, p. 305), are well visible only in juvenile specimens.

Material examined: 18 specimens (UJMC 451).

Conservation status: N5.

Remarks. Shells of this species are extremely variable in morphology so its taxonomy is therefore not well-defined (Kuiper et al., 1989). However, the hinge

structure and especially the cardinal teeth are a useful diagnostic distinguishing feature. *Euglesa casertana* (Poli, 1791) (former *Pisidium casertanum*) and *P. milium* Held, 1836, show similar C3 tooth but, unlike *P. nitidum*, their respective C2 teeth are shorter than their C4. Molecular studies pointed out that *P. nitidum* and *P. milium* are sister species (Lee & Ó Foighil, 2003) which explains the mentioned similarities in the hinge structure.

Genus *Euglesa* Jenyns, 1832

Type species: *Tellina pusilla* Gmelin, 1791
Euglesa compressa (Prime, 1852)
 (Fig. 3D)

Taxonomic summary

Description. Triangular in shape; hinge of the left valve long and curved, laterals short, C2 stump-like, resembling an inverted D, low, C4 short and thin, very slightly curved, directed toward cusp of P2, A2 high and strong, P2 less high, both with blunt, central cusps (Mackie & Huggins, 1983).

Material examined: 2 specimens (UJMC 452).

Conservation status: N4-N5.

Remarks. Herrington (1962) and Mackie and Huggins (1983) mentioned that *Pisidium compressum* (= *Euglesa compressa*) and *P. ultramontanum* have almost the same hinge characteristics. However, the last species, endemic to northeastern California and south-central Oregon, is rounded in outline, while shells of *E. compressa* are, according to the original description, more triangular (Prime, 1852, p. 219, Plate VI). There are few reports of this species in Mexico, but information about the exact location is lacking (Contreras-Arquieta, 2000). Fossil and sub-recent records have shown that this species had a

wide and highly dense distribution in the region (Czaja, Estrada-Rodríguez et al., 2014; Czaja, Estrada-Rodríguez, Romero-Méndez & Orona-Espino, 2017).

Genus *Eupera* Bourguignat, 1854

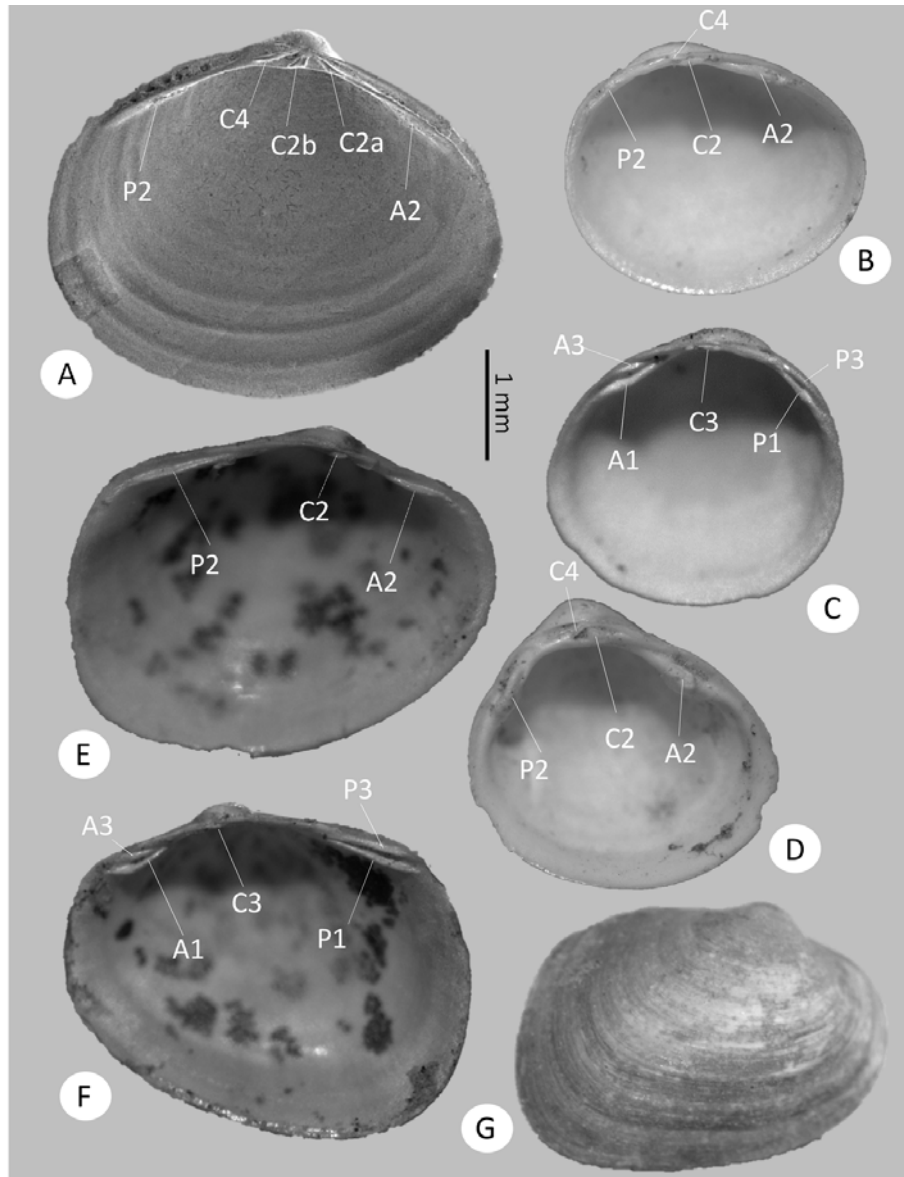
Type species: *Pisidium moquinianum* Bourguignat, 1854

Eupera cubensis (Prime, 1865)

(Fig. 3E-G)

Taxonomic summary

Description: Shell oval to trapezoidal; lateral tooth P2 long and almost straight, C2 very short and high; A2 straight and half as long as P2 (Fig. 3E); P1 and P3 long and straight, C3 low, short and stump-like, A1 short, slightly curved (Fig. 3F); A3 low and short; inner faces of all laterals in right valve with numerous brown dots (Mackie & Huggins, 1983).



Figures 3. Bivalves from Sabinas River basin. A, *Corbicula fluminea* (UJMC 450a), left valve. B, *Pisidium nitidum* (UJMC 451a), left valve. C, (UJMC 451b), right valve. D, *Euglesa compressa* (UJMC 452a) left valve. E, *Eupera cubensis* (UJMC 453a), left valve. F, *E. cubensis* (UJMC 453b), right valve. G, *E. cubensis*, external view of right valve. A1 = Anterior lateral internal tooth, A2 = anterior lateral tooth, A3 = anterior lateral external tooth, C2 (a, b) = internal cardinal tooth, C3 = cardinal tooth, C4 = external cardinal tooth, P1 = posterior lateral internal tooth, P2 = posterior lateral tooth, P3 = posterior lateral external tooth.

Material examined: 17 specimens (UJMC 453).

Conservation status: N4.

Remarks. The mottled fingernail clam is well characterized by the general rhomboidal form (Fig. 3G), delicate shells, 1 cardinal tooth in each valve and especially by the blackish-brown cluster of dots (Fig. 3E, F), notorious on the drawing of the original description by Prime (1865, p. 58. fig. 60). Contreras-Arquieta (2000) reported the occurrence of *Eupera insignis* Pilsbry (1925) (= synonym of *E. cubensis*) in Mexico but without any information on the exact location. According to our observations, this species seems to be common at least in northern Mexico (Coahuila, Durango, Chihuahua).

Class Gastropoda

Order Caenogastropoda (temporary name)

Superfamily Cerithioidea J. Fleming, 1822

Family Thiaridae Gill, 1871 (1823)

Genus *Melanoides* Olivier, 1804

Type species: *Melanoides tuberculata* (O. F. Müller, 1774)

Melanoides tuberculata (O. F. Müller, 1774) (Invasive species)

(Fig. 4A)

Taxonomic summary

Description. Shells turreted, dark brown with numerous reddish-brown streaks, exhibit great morphological variation related to size and, specifically, sculptures and ornaments; protoconch smooth; teleoconch with spiral grooves (Fig. 4A), some specimens with axial undulating ribs; with 6-10 slightly rounded whorls; aperture oval, operculum paucispiral with the nucleus near the base.

Material examined: > 400 specimens (UJMC 454).

Conservation status: N5.

Remarks. The first report of established populations of the invasive Red-Rim *Melania* in the Sabinas River is from 1994 (Contreras-Arquieta, 1998). The author described 3 sites on the Sabinas River (near the city of Múzquiz), where the density of *M. tuberculata* increased downstream. This increase is interpreted as a consequence of increasing eutrophic conditions downstream, caused by the pollution of the river by agriculture and mining.

Currently, the Red-Rim *Melania* is present in all sampled localities but especially abundant in sites 6-9. Although there is much evidence that this species can outcompete populations of native snails (Karatayev et al., 2009; Pointer, 1993), this has never been proven empirically. Our observations from the last 6 years in northern Mexico indicate decreases in native snail population. Especially, communities with hydrobid and cochliopid snails belong to the most affected groups by the presence of *Melanoides* (Czaja, Covich et al., 2019; personal unpublished data).

Order Littorinimorpha Golikov & Starobogatov, 1975

Superfamily Truncatelloidea Gray, 1840

Family Lithoglyphidae Tryon, 1866

Genus *Phreatomascogos* Czaja & Estrada-Rodríguez, 2019

Type species: *Phreatomascogos gregoi* Czaja & Estrada-Rodríguez, 2019

Phreatomascogos gregoi Czaja & Estrada-Rodríguez, 2019

(Fig. 4B)

Taxonomic summary

Description. Shell small, valviform, varying in shape from (mostly) flat-trochoid to (rarely) low conical, height 0.65-0.99 mm, width 1.22-1.54 mm; umbilicus almost completely covered by a basal keel of the body whorl; protoconch smooth; teleoconch with 3¼ or fewer rounded whorls with less prominent axial growth lines, the border between protoconch and teleoconch approximately after 1.5 whorls (Czaja, Cardoza-Martínez et al., 2019, p. 93).

Material examined: 56 specimens (UJMC 400-407, UJMC 455).

Conservation status: N2.

Remarks. This recently described endemic species likely inhabits the interstitial space within the water-saturated underground gravel layer of the hyporheic zone (Czaja, Cardoza-Martínez et al., 2019).

Family Cochliopidae Tryon, 1866

Genus *Balconorbis* Hershler & Longley, 1986

Type species: *Balconorbis uvaldensis* Hershler & Longley, 1986

Balconorbis sabinasensis Czaja, Cardoza-Martínez & Estrada-Rodríguez, 2019

(Fig. 4C, D)

Taxonomic summary

Description. Shell minute, planispiral, width 1.51-1.81 mm, height 0.42-0.61 mm, with 3¼-3¾ whorls; protoconch smooth to slightly pitted, hidden in ventral view, has 1¼ whorls, first teleoconch whorl with strong and elevated axial growth lines which cross the spiral lines producing a square pattern, about 80 elevated spiral lines are present on the body whorl, body whorl with 1 or 2 keels, 1 keel usually stronger; aperture rounded to ovate (Czaja, Cardoza-Martínez et al., 2019, p. 95-96).

Material examined: 31 specimens (UJMC 410, 411, UJMC 456).

Conservation status: N2.

Remarks. The genus has 2 species distributed in Texas (Edwards Aquifer) and the Sabinas River (Coahuila), respectively. Both species have shells with a characteristic

spiral structure that is unique among all other subterranean snails.

Genus *Coahuilix* Taylor, 1966

Type species: *Coahuilix hubbsi* Taylor, 1966

Coahuilix parrasense Czaja, Estrada-Rodríguez, Romero-Méndez, Ávila-Rodríguez, Meza-Sánchez & Covich, 2017
(Fig. 4E)

Taxonomic summary

Description. Shell small, planispiral, 1.33-1.57 mm wide and 0.38-0.49 mm high, with 3-3¼ whorls, protoconch smooth to slightly pitted, hidden in apertural view, has 1¼ whorls, first teleoconch whorl with strong and elevated growth lines, subsequent whorls with fine growth lines, aperture rounded to ovate, apertural plane highly inclined (> 60°) relative to shell axis well inside the aperture 1 or (mostly) 2 tooth-like bulges (Czaja, Estrada-Rodríguez, Romero-Méndez, Ávila-Rodríguez et al., 2017, p. 230).

Material examined: 2 specimens (UJMC 416, 417).

Conservation status: N2.

Remarks. *Coahuilix parrasense* was described originally as a sub-fossil species from a dried-up stream near Parras de la Fuente, Coahuila. Posteriorly, this species was found in the Sabinas River, Coahuila and Nazas River, Durango (Czaja, Cardoza-Martínez et al., 2019; Czaja, Estrada-Rodríguez, Romero-Méndez & Orona-Espino, 2017).

Genus *Cochliopina* Morrison, 1946

Type species: *Cochliopina riograndensis* Pilsbry & Ferriss, 1906

Cochliopina riograndensis Pilsbry & Ferriss, 1906
(Fig. 4F, G)

Taxonomic summary

Description. Shell valvuliform, small, broadly heliciform, slightly olive to nearly transparent, up to 3.42 mm in width, openly umbilicate; with 4-4½ whorls, apical whorl with pitted structure; teleoconch nearly smooth or with spiral threads on the body whorl, 1 thread at the shoulder usually more prominent, with up to 10 dark brown pigmented bands (Fig. 4G), bands well visible especially on the threads, whorls moderately convex with deep sutures; the aperture is roundly ovate and angled toward the apex; peristome thin, inner lip partly fused to the penultimate whorl.

Material examined: 132 specimens (UJMC 457).

Conservation status: N3.

Remarks. *Cochliopina riograndensis* has been reported mostly as an epigeal species but Alvear et al. (2020) mentioned that in Texas this snail also potentially occupies

aquifer and hyporheic habitats. We found evidence also in the Sabinas River that *C. riograndensis* occurs in both interstitial and epigeal environments. We suppose that this snail occurs in the area of study generally with 2 different ecophenotypic populations: 1) specimens with large shells with multiple brown pigmented bands, and 2) small shells without such distinctive spiral threads and nearly transparent.

Genus *Juturnia* Hershler, Liu & Stockwell, 2002

Type species: *Durangonella coahuilae* Taylor, 1966

Juturnia coahuilae (Taylor, 1966)
(Fig. 4H, I)

Taxonomic summary

Description. Shell 2.5-3.3 mm long, 1.2-1.4 mm wide, smooth, slender and turritiform, protoconch smooth, teleoconch with 5½-6 strongly convex and smooth whorls, teleoconch sculpture with closely spaced growth lines, aperture nearly circular or rounded, inner lip thin to slightly thickened.

Material examined: 6 specimens (UJMC 458).

Conservation status: N2N3.

Remarks. Morphologically, the shells from the Sabinas River (Figs. 4H, I) are identical to those described by Taylor (1966, p. 184) and Hershler (1985, p. 83) from the type locality of this species and to Pleistocene material described from Coahuila (Czaja, Covich et al., 2019; Czaja, Palacios-Fest et al., 2014). Six transparent specimens of *J. coahuilae* were found in muddy sediments at the site 6 (Las Adjuntas). The fine and closely spaced growth lines on the teleoconch is characteristic feature of this species, which previously was known only as endemic to the spring complex of the Cuatro Ciénegas basin, Coahuila.

Genus *Mexithauma* Taylor, 1966

Type species: *Mexithauma quadripaludium* Taylor, 1966
Mexithauma cf. *quadripaludium* Taylor, 1966
(Fig. 4J, K)

Taxonomic summary

Description. Shell fragment with protoconch and following 3 whorls (without body whorl); protoconch smooth; teleoconch with 3 strong spiral cords, first cord beginning after approximately 1½ whorls (Fig. 4J), with remains of brownish periostracum bands above the first cord.

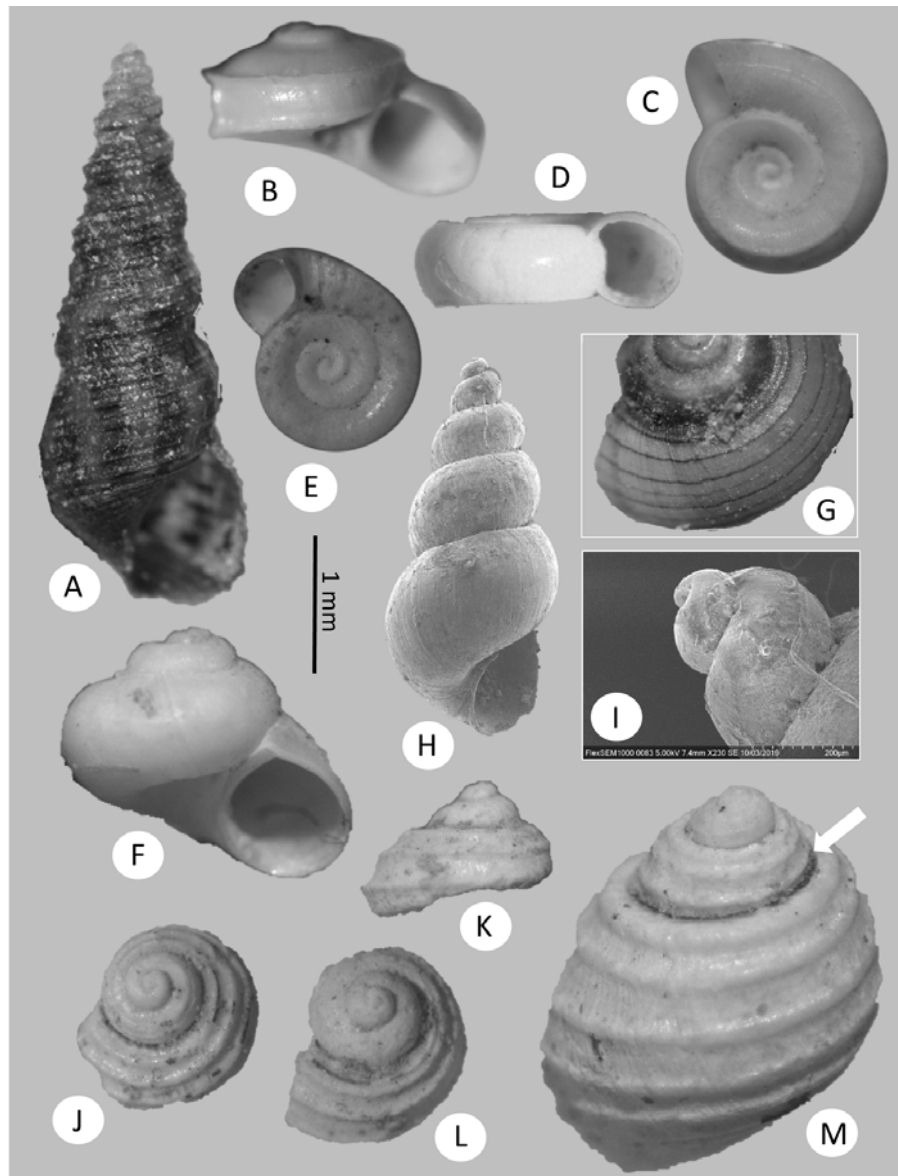
Material examined: 1 specimen, fragment (UJMC 459).

Conservation status: N2.

Remarks. Although only a fragment of the apex without body whorl was found, the general features and

details of the shell are so characteristic that there is little doubt about the generic assignment of this fragment. We found various striking similar shell fragments at the Poza Azul, Cuatro Ciénegas basin (Fig. 4L). It seems that similar fragments arise because of (fish) predation, where the shells frequently break off exactly at the same point (Fig. 4J, L, M with arrow) between the body whorl and

the second whorl. The preserved remains of brown bands on the shell fragment indicate that it is not a fossil but a recent specimen. Since they are made of organic material (thin periostracum), these bands are microbially degraded shortly after the death of the snail and thus are rarely preserved in the fossil record (own observations in Cuatro Ciénegas).



Figures 4. Gastropods from Sabinas River basin, Coahuila. A, *Melanoides tuberculata* (UJMC 454a). B, *Phreatomascogos gregoi* (UJMC 401). C, *Balconorbis sabinasensis* (UJMC 410). D, Apertural view. E, *Coahuilix parrasense* (UJMC 416). F, *Cochliopina riograndensis* (UJMC 457a). G, shell with brown-pigmented bands (UJMC 457b). H, *Juturnia coahuilae* (UJMC 458a). I, apex of *J. coahuilae* (UJMC 458b). J-M, *Mexithauma* cf. *quadripaludium*. J, K, specimen from Sabinas with broken apex with first whorls (UJMC 459). L, similar broken apex of specimen from Poza Azul in Cuatro Ciénegas. M, complete shell from Poza Azul, Cuatro Ciénegas, arrow shows the break point on the shell (L-M belong to own collection).

Since *Mexithauma* is a monotypic genus, the Sabinas shell fragment belongs most likely to this endemic form from Cuatro Ciénegas basin (*M. quadripaludium* Taylor). However, this cannot be concluded with complete certainty from the fragment itself, thus we considered it as not sufficient for an exact specific assignment. Pending further findings of living specimens, we tentatively assigned this species with a N2 rank.

Genus *Pyrgophorus* Ancey, 1888

Type species: *Pyrgulopsis spinosus* Call & Pilsbry, 1886
Pyrgophorus parvulus (Guilding, 1828)
(Fig. 5A, B)

Taxonomic summary

Description. Shell with carinae modified to conical spines (Fig. 5A), spines darker than teleoconch, with 4-6 ½ whorls, first 2 whorls rounded and without spines on carinae, suture not deep; the lower part of the teleoconch with spiral striae which are visible on the penultimate and body whorl (Fig. 5B), body whorl large; of light green color, nearly white on apex; aperture roundly ovate, peristome not continuous, sharp.

Material examined: 28 specimens (UJMC 460).

Conservation status: N4.

Remarks. More than 30 nominal species were described from North, Central and South America based on shell-morphology and caused a taxonomic chaos in this genus (Hershler & Thompson, 1992). We have compared our material from Coahuila directly with shells of *Pyrgophorus* from many sites in Mexico, including Quintana Roo (approximately 2,500 km SE), and we did not detect any significant differences. Only *P. cenoticus* Grego, Angyal & Beltrán, 2019, a stygobiont species endemic to the Cenote Xoch in Yucatán, Mexico, has a distinguishable morphology of the shell (Grego et al., 2019). We agree with Hershler & Thompson (1992, with a list of synonyms) and considered that all other described *Pyrgophorus* forms belong (at least morphologically) to one polymorphic and wide distributed species. The first shells of such spinose morphology were collected in Jamaica and described as *Paludina parvulus* Guilding (1828). This designation seems to be the oldest name for such shells and, therefore, should be used.

Family Amnicolidae Tryon, 1863

Genus *Lyogyrus* Gill, 1863

Type species: *Valvata pupoidea* Gould, 1839

Lyogyrus sp.

(Fig. 5C-G)

Taxonomic summary

Description. Shell small, 1.62 mm in height and 1.14 mm in width, umbilicate, with faint growth lines; apex obtuse, protoconch depressed and flat (Figs. 5D, E), protoconch microsculpture of fine fimbriations (Fig. 5G); teleoconch with 4 extremely convex whorls (Fig. 5C-E), apical whorls flattened, body whorl slightly detached from the proceeding whorls, whorls sculptured with growth striations crossed by weak spiral lines on the lower part of the body whorl (Fig. 5E), with deeply impressed sutures, aperture small, almost perfectly rounded, 0.75 mm in diameter.

Material examined: 1 specimen (UJMC 461).

Conservation status: N2.

Remarks. Although only a single specimen was found, this shell from Sabinas provides congruent morphological evidence that it belongs to one of the genera in the family Amnicolidae. The general shape and details of the characteristic shell protoconch and teleoconch structure, visible on the SEM micrographs, show clearly that the specimen belongs to the genus *Lyogyrus*, probably a new species. Snails of the others members of the family in North America (*Amnicola*, *Dasyscia*, *Colligyris*) have different shaped shells with larger apertures and less convex whorls.

The genus *Lyogyrus* has been little studied taxonomically and currently 9 species are recognized, differentiated merely by shell features. Only from *L. pupoides*, distributed in northern Atlantic Coastal drainage, and from *Lyogyrus* sp. (masked duskysnail, northwestern USA) exists DNA sequences (Liu et al., 2016). Our shell from the Sabinas River is similar to both shells of *L. walkeri* from Waubasacan Lake, Michigan, and *Lyogyrus* sp. Upsata Lake, Montana, illustrated by Liu et al. (2016, fig. 7A- C). However, there are detectable differences; the shell from Coahuila is approximately a third smaller in length and has other peristome features compared to those from USA. In the original description of *L. walkeri* (Pilsbry, 1898), Pilsbry especially emphasizes the “very convex” whorls and the “rather small” aperture. Both shell features apply exactly to our specimen. However, there are no molecular data of *L. walkeri* and, despite anatomical and molecular investigations, also the taxonomic status of the western masked duskysnail and its relation to *L. walkeri* have not been resolved (Liu et al., 2016). The authors recommend treating such snails as *Lyogyrus* sp., and we follow this recommendation for our shell from Sabinas until living specimens can be found. This is the first record of a member of the family Amnicolidae in Mexico.

Family Hydrobiidae Troschel, 1857

Genus *Cincinnatia* Pilsbry, 1891

Type species: *Paludina integra* Say, 1821
Cincinnatia integra (Say, 1821)
 (Fig. 5H)

Taxonomic summary

Description. Shell sub-globose to ovate-conic, height 3.9-4.8 mm, with 4½ strongly inflated whorls, with pronounced shoulder, suture deeply impressed, apex acute, slightly convex, protoconch dome-like and smooth,

aperture large and oval (detailed shell and opercula description by Hershler et al. [2011] and sub-fossil shells by Czaja, Estrada-Rodríguez, Romero-Méndez, Estrada-Arellano et al. [2017]).

Material examined: 10 specimens (UJMC 462).

Conservation status: N2N3.

Remarks. In USA, *C. integra* is a common species but its occurrence in the Sabinas River represents the second report from Mexico. Morphologically, our material

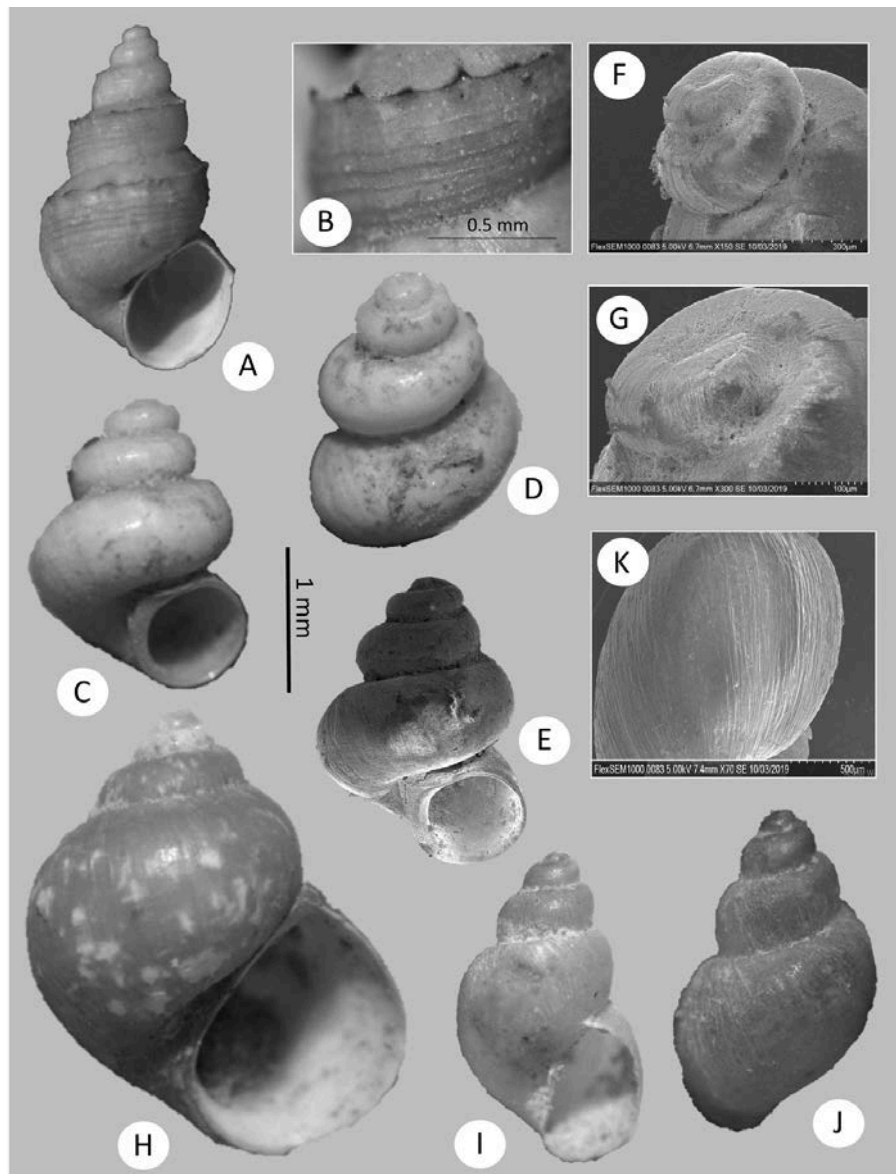


Figure 5. Gastropods from Sabinas River basin, Coahuila (cont.). A, *Pyrgophorus parvulus* (UJMC 460a). B, details of the teleoconch from same specimen. C-G, *Lyogyrus* sp. (UJMC 461). C, rounded aperture. D, showing the extremely convex whorls, E, SEM image of the shell. F, G, details of the protoconch. H, shell of *Cincinnatia integra* (UJMC 462a). I, apertural view of *Galba* sp. (*G. humilis* species complex) (UJMC 463a). J, dorsal view. K, SEM image showing the coarse and wavy growth lines on the body whorl (UJMC 463b).

from the Sabinas River is identical to shells from Rio La Ciénega, Veinte de Noviembre, San Luis Potosi, the other locality recorded for this species. Many fossil records shown that *C. integra* can be considered in Mexico as a Pleistocene relict (Czaja, Estrada-Rodríguez, Romero-Méndez, Estrada-Arellano et al., 2017).

Superorder Hygrophila Férussac, 1822

Superfamily Lymnaeoidea Rafinesque, 1815

Family Lymnaeidae Rafinesque, 1815

Genus *Galba* Schrank, 1803

Galba sp. (*G. humilis* species complex *sensu* Alda et al., 2019)

(Fig. 5I-K)

Taxonomic summary

Description. Shells up to 4.32 mm in height, protoconch and first whorl smooth, without visible microsculpture; teleoconch sculpture with many coarse and wavy growth lines (Figs. 5J, K) beginning after the first whorl; with 4-4½ whorls, whorls rounded and slightly shouldered, last whorl about half the length of the shell; aperture elongated and shouldered at its junction with body whorl.

Material examined: 12 specimens (UJMC 463).

Conservation status: N5.

Remarks. In their recent molecular revision of the genus, Alda et al. (2019) proposed that the genus *Galba* comprises 5 species (or species complexes) and that only *Galba cousini* from South America can be determined using shell morphology and internal anatomy. Since all the 5 species have shells morphologically indistinguishable from each other, we attributed our material tentatively to the *G. humilis* species complex *sensu* Alda et al. (2019).

Family Physidae Fitzinger, 1833

Genus *Physella* Haldeman, 1842

Physella acuta (Draparnaud, 1805)

(Fig. 6A, B)

Taxonomic summary

Description. Shells up to 12.2 mm long but mainly smaller (4-6 mm), elongate-ovate; protoconch smooth, without visible sculpture, rounded; with 4-5 whorls, teleoconch with faint spiral growth lines, spire short with first whorls minute, the body whorl very large, suture slightly deep, body whorl approximately 85% of shell length; aperture large, ear-shaped, outer lip thin, inner lip closely appressed to the columellar region.

Material examined: 48 specimens (UJMC 464).

Conservation status: N5.

Remarks. Shells of *Physella acuta* based on topotypic specimens from France have been well-characterized by

Paraense and Pointier (2003) and posteriorly, with North American specimens, by Wethington et al. (2009). Our material from the Sabinas River is identical with these shells and therefore we located it into this cosmopolitan species.

Family Planorbidae Rafinesque, 1815

Genus *Biomphalaria* Preston, 1910

Type species: *Biomphalaria smithi* Preston, 1910 (type by original designation)

Biomphalaria havanensis (L. Pfeiffer, 1839)

(Fig. 6C-E)

Taxonomic summary

Description. Shells medium sized (maximum diameter 9.07 mm), flattened, discoidal (flat spiral), ultradextral; with 3-4¾ rounded whorls, whorls increasing moderately in diameter; spire concave and flattened, umbilicus as a shallow depression (Fig. 6D); sculpture of fine lines of growth pronounced and irregular on the body whorl (Fig. 6C), whorls separated by deep sutures; aperture ovate, without apertural lamellae (Fig. 6E).

Material examined: 25 specimens (UJMC 465).

Conservation status: N5.

Remarks. The taxonomic history and systematics of the members of the genus *Biomphalaria* are long and confusing (DeJong et al., 2001). Similar shells to our material from Sabinas have been described from many sites in North and Central America as *B. obstructa* or *B. havanensis*. Morphologically, the 2 “species” are indistinguishable and recent molecular studies of Aguiar-Silva et al. (2014) and Rosser et al. (2016) confirmed that *B. obstructa* should be considered as younger synonym of *B. havanensis*.

Genus *Gyraulus* Charpentier, 1837

Type species: *Planorbis albus* O. F. Müller, 1774 (type by subsequent designation)

Gyraulus parvus (Say, 1817)

(Fig. 6F-H)

Taxonomic summary

Description. Shell small (up to 4.5 mm in diameter), discoidal, depressed, pale brown; with 2-3 whorls; with fine well visible growth-lines (Fig. 6E); spire flat, slightly depressed; umbilicus wide (Fig. 6F), shallow; all whorls are notorious from above and below (in contrast to *Menetus dilatatus*); aperture ovate, deflected below; outer and inner lip thin (Fig. 6H).

Material examined: 14 specimens (UJMC 466).

Conservation status: N4N5.

Remarks. The entire group with similar shelled forms such as *G. parvus*, *G. deflectus* and *G. circumstriatus*

urgently needs a revision. Most similar to *G. parvus* is undoubtedly *G. circumstriatus*, but its shells have more whorls and the last one does not enlarge so rapidly like in *G. parvus* (Fullington, 1978).

Genus *Hebetancylus* Pilsbry, 1914

Type species: *Ancylus moricandi* Orbigny, 1837

Hebetancylus excentricus (Morelet, 1851)

(Fig. 6I)

Taxonomic summary

Description. Shell elliptical in form, apex behind the middle of the shell, distinctly to the right of the midline, blunt and smooth, without radial striations (Fig. 6I); anterior slope slightly convex, the posterior slope concave; prominent concentric growth lines (radial sculpture) below the apical region, mostly well visible but often also incomplete or missing.

Material examined: 15 specimens (UJMC 467).

Conservation status: N4N5.

Remarks. The original description of Morelet (1851) is very brief and without figures. The main shell features distinguishing this species from other limpets (*Ferrissia*, *Laevapex*) seem to be the distinctly right of the midline located apex (called by Morelet “*lateralis*”), and the clearly defined radial sculpture.

Genus *Helisoma* Swainson, 1840

Type species: *Planorbis bicarinatus* Say, 1819

Helisoma anceps (Menke, 1830)

(Fig. 6J-M)

Taxonomic summary

Description. Shell of moderate size, 8.2 mm in diameter, dextral, pale brown, 3¾ whorls, whorls carinated (2 prominent ridges) above and below (Fig. 6J, K) and rapidly enlarging, carinae rounded, upper carina at the center of the whorl; all whorls of the spire deeply immersed (unlike *Planorbella trivolvis*, see below); nucleus and the first third of the protoconch smooth (Fig. 6M), rest of protoconch with fine growth lines; umbilicus deep and narrow (Fig. 6K); teleoconch with regular, more or less radial riblets, which are, especially below the carina on the body whorl, crossed by wavy spiral threads (Fig. 6J); aperture ear-shaped, suddenly expanded (Fig. 6L).

Material examined: 6 specimens (UJMC 468).

Conservation status: N5.

Remarks. Shells of the Two-ridge Ramshorn snail are well differentiated from the following 2 planorbiid species by having 2 ridges (1 of each side) and a very deeply immersed spire and umbilicus and the above mentioned shell structure details. *Helisoma anceps* is a more northern

species of cooler climate, very common throughout eastern USA (Fullington, 1978).

Genus *Menetus* H. Adams & A. Adams, 1855

Type species: *Planorbis dilatatus* Gould, 1841

Menetus dilatatus (A. Gould, 1841)

(Fig. 7A-C)

Taxonomic summary

Description. Shell small, ultradextral, flattened, discoidal (flat spiral), with few rapidly enlarging whorls; body whorl with less well-developed carina (keel), placed just above the center of the body; with 3 whorls, whorls rapidly increasing in size, sculpture of fine lines of growth; umbilicus deep (7C), all whorls visible only from above; aperture large, expanded; lips slightly thickened.

Material examined: 11 specimens (UJMC 469).

Conservation status: N3N4.

Remarks. In the present-day *Menetus dilatatus* has a broad distribution across the USA from Florida and Texas into Canada (Baker, 1945; Burch, 1989). Published records from Mexico are still known only from 2 sites in Zacatecas and Puebla (Albrecht et al., 2007; Thompson, 2011) and from streams of Coahuila (Nazas River) and Durango (Peñón Blanco River) (Czaja et al., 2020 and personal observations).

Genus *Planorbella* Haldeman, 1843

Type species: *Planorbis campanulatus* Say, 1821

Planorbella cf. *trivolvis* (Say, 1817)

(Fig. 7D-G)

Taxonomic summary

Description. Shell of medium size, brown, 11-15 mm in diameter, height about half of the diameter; spire deeply immersed but nucleus and first whorl slightly elevated (Fig. 7G, H), nucleus of protoconch smooth to slightly pitted (Fig. 7G), the remaining part of the protoconch with axial stripes; teleoconch with 4-4½ whorls, rapidly enlarging, inner 3 whorls nearly flat and, in contrast to *H. anceps*, not deeply immersed (Fig. 7E), right side deeply umbilicate so that only 2 whorls are visible (Fig. 7D), with 1 poorly developed carinae (Fig. 7E); aperture is angular above and rounded below, lower margin of aperture advanced beyond upper margin.

Material examined: 7 specimens (UJMC 470).

Conservation status: N5.

Remarks. Some species of the genus *Planorbella* such as *P. duryi* and *P. trivolvis*, are conchologically difficult to separate and the whole complex urgently needs a revision. The original description of *Planorbis trivolvis* of Say (1817) is very brief, so we also used the original

description of 2 synonyms: *Planorbis lentus* Say, 1834 and *Planorbis intertextus* Sowerby, 1878. We described our material tentatively as *P. cf. trivolvis* due to the fact that the majority of the shell properties coincide with the descriptions (and figures) of the mentioned synonyms (in Say, 1834 as *Planorbis lentus* Say, 1834). It seems that this species differs from the similar shelled *P. duryi* in having characteristic regular radial riblets that reach almost to the nucleus (Fig. 7G) while the complete protoconch of

P. duryi is almost smooth. If this is a sure diagnostic difference, it should to be shown in further studies.

Planorbella scalaris (Jay, 1839)
 (Fig. 7H)

Taxonomic summary

Description. Shell small, height 3.02 mm, wide 2.83 mm, spire slightly raised above the body whorl when

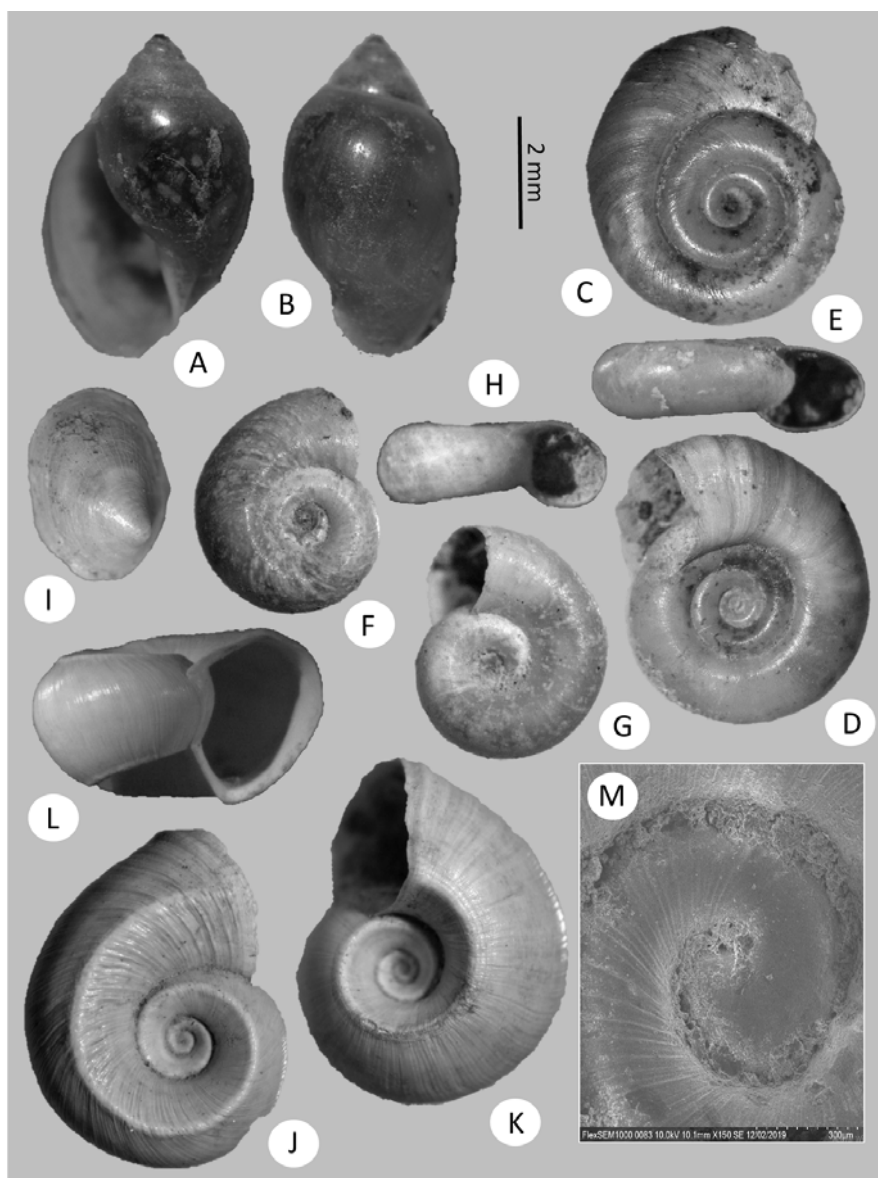


Figure 6. Gastropods from Sabinas River basin, Coahuila (cont.): A, *Physella acuta* (UJMC 464a), apertural view. B, dorsal view. C, D, *Biomphalaria havanensis* (UJMC 465a) shell from dorsal and ventral side. E, Apertural view, F, G, *Gyraulus parvus* (UJMC 466a), shell from dorsal and ventral side. H, Apertural view, I, *Hebetancylus excentricus* (UJMC 467a), shell with prominent concentric growth lines. J-K, *Helisoma anceps* (UJMC 468a), shell from dorsal and ventral side. L, Apertural view, M, protoconch.

viewed from lateral (Fig. 7H), flat-topped; nucleus of protoconch smooth to slightly pitted, 160 μ m in diameter, rest of the protoconch with fine growth lines; teleoconch with strong growth lines crossed by spiral lines; deeply umbilicated; lower margin of aperture not advanced beyond upper margin.

Material examined: 2 specimens (UJMC 471).

Conservation status: N4.

Remarks. The 2 shells from the Sabinas River resemble in all details shells of *Planorbella scalaris*, described

originally as *Paludina scalaris* from the Everglades (Florida, USA) by Jay (1839, Plate 1, Figs. 8, 9). Similar shells have also been described frequently as *P. duryi* forma *seminole* but without any taxonomic legitimacy. Therefore, we considered that such shells should be denominated *P. scalaris*, unless the affiliation with *P. duryi* can be proved. Fossil *scalaris*-like *Planorbella* shells were already described from the late Pleistocene Paleolake Irritila, Coahuila, approximately 150 km southern of the area of study, by Czaja, Estrada-Rodríguez et al. (2014).

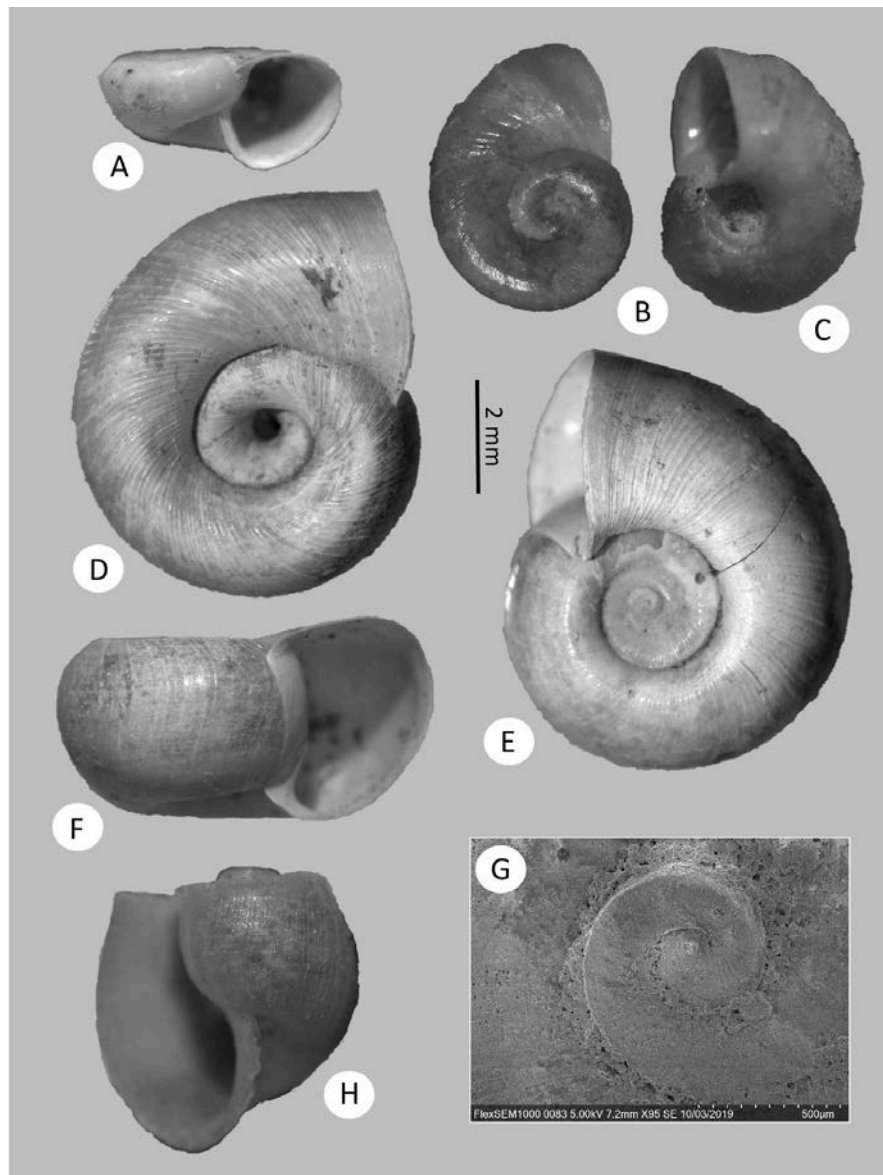


Figure 7. Gastropods from Sabinas River basin, Coahuila (cont.): A-C, *Menetus dilatatus* (UJMC 469a), shell from dorsal and ventral side (UJMC 469b) D-G, *Planorbella* cf. *trivolvis* (UJMC 470a), shell from dorsal and ventral side. G, protoconch, H, *Planorbella scalaris* (UJMC 471).

The Mesa Rams-horn was described originally as endemic to Florida marshes and lakes in the central and southern part of the peninsula, particularly from the Everglades, South Florida (Baker, 1945; Burch, 1989; Thompson, 1999). Nevertheless, the abundance of fossil records from the region shows that this species can be considered as a native form in the Sabinas River (Czaja, Palacios-Fest et al., 2014).

Molluscan diversity and species richness. From 9 sites, the occurrence of 23 (19 gastropods and 4 bivalves) species are reported (Table 2). Of the 14 mollusc families present in Mexico, 10 occur in the area of study. Planorbidae is the most diverse family with 7 species, followed by Cochliopidae (6) and Sphaeriidae (3) (Fig. 8). In total, 22 genera are present where Planorbidae and

Cochliopidae dominate each with 6 genera, followed by Sphaeriidae (3). The malacofauna contains 1 endemic genus (*Phreatomascogos*) and 2 endemic species belong to cochliopiid and lithoglyphiid families. *Lyogyrus* sp. (possibly a new species) is the first member of the Amnicolidae family found in Mexico. Finally, 2 invasive species were found (*Melanoides tuberculata* and *C. fluminea*).

Species richness per site (Fig. 9) ranged from 4 to 22 and was greatest at site 6 (Las Adjuntas), where 22 of the 23 species were found. At other sites the diversity is relatively low (4-10 species). *Melanoides tuberculata* is the most abundant gastropod and was present at all 9 sites, followed by *C. riograndensis* (7 sites), *P. gregoi* (6) and *H. excentricus* (5) (Fig. 10). *Coahuilix parrasense*, *J.*

Table 2

List of molluscan species from Sabinas River basin with their conservation rank and site of occurrence. E = Endemic, ECC = endemic in Cuatro Ciénegas; NatureServe-Rank-Conservation status: N1 = critically imperiled, N2 = imperiled, N3 = vulnerable, N4 = apparently secure, N5 = secure; 1-9 = number of the studied sites (see Table 1).

Family	Species	Endemic	N-Rank	Site
Cyrenidae	<i>Corbicula fluminea</i> (O. F. Müller, 1774)	—	N5	3, 4, 5, 6, 7, 8, 9
Sphaeriidae	<i>Pisidium nitidum</i> Jenyns, 1832	—	N5	2, 3, 6, 8
Sphaeriidae	<i>Euglesa compressa</i> (Prime, 1852)	—	N4N5	2, 6
Sphaeriidae	<i>Eupera cubensis</i> (Prime, 1865)	—	N3	4, 6, 8
Thiaridae	<i>Melanoides tuberculata</i> (O. F. Müller, 1774)	—	N5	1, 2, 3, 4, 5, 6, 7, 8, 9
Lithoglyphidae	<i>Phreatomascogos gregoi</i> Czaja & Estrada-Rodríguez, 2019	E	N2	1, 2, 5, 6, 7, 9
Cochliopidae	<i>Balconorbis sabinasensis</i> Czaja, Cardoza-Mart. & Estrada-Rodríguez, 2019	E	N2	2, 5, 6, 9
Cochliopidae	<i>Coahuilix parrasense</i> Czaja et al. 2017	E	N2	6
Cochliopidae	<i>Cochliopina riograndensis</i> Pilsbry and Ferriss, 1906	—	N3	2,4,5,6,7,8,9
Cochliopidae	<i>Juturnia coahuilae</i> (Taylor, 1966)	(ECC)	N2	6
Cochliopidae	<i>Mexithauma cf. quadripaludium</i> Taylor, 1966	(ECC)	N2	5
Cochliopidae	<i>Pyrgophorus parvulus</i> (Guilding, 1828)	—	N4	6, 7, 8, 9
Amnicolidae	<i>Lyogyrus</i> sp.	—	N2	6
Hydrobiidae	<i>Cincinnatia integra</i> (Say, 1821)	—	N2N3	2, 4
Lymnaeidae	<i>Galba</i> sp.	—	N5	4, 6, 7, 9
Physidae	<i>Physella acuta</i> (Draparnaud, 1805)	—	N5	2, 3, 5, 6, 8, 9
Planorbidae	<i>Biomphalaria havenensis</i> (L. Pfeiffer, 1839)	—	N5	1, 2, 6, 8
Planorbidae	<i>Gyraulus parvus</i> (Say, 1817)	—	N4N5	2, 4, 6, 8
Planorbidae	<i>Hebentancylus excentricus</i> (Morelet, 1851)	—	N5	1, 4, 5, 6, 7
Planorbidae	<i>Helisoma anceps</i> (Menke, 1830)	—	N5	2, 4, 6
Planorbidae	<i>Menetus dilatatus</i> (Gould, 1841)	—	N3N4	4, 6, 8
Planorbidae	<i>Planorbella cf. trivolvis</i> (Say, 1817)	—	N5	6, 7, 9
Planorbidae	<i>Planorbella scalaris</i> (Jay, 1839)	—	N4	2, 9

coahuilae, *Lyogyrus* sp. and *M. cf. quadripaludium* were found only at 1 site, and the last 2 species with a single specimen. *Corbicula fluminea* is by far the most common bivalve present at 7 sites followed by *P. nitidum* (4).

As an important result of our study, we consider the new records of members of the genera *Coahuilix*, *Juturnia* and *Mexithauma*. Previously, these gastropods had been known as endemic species exclusively from the Cuatro Ciénegas basin. Other, extremely rare species in Mexico, such as *C. integra*, *C. riograndensis* and the clam *E. cubensis* have their habitat in the Sabinas River.

Conservation status. We assessed the new records of *J. coahuilae*, *Lyogyrus* sp. and *M. cf. quadripaludium* tentatively as (at least) imperiled because these species were found with few specimens and only at 1 site. According to our assignment, none of the species present at the Sabinas River are critically imperiled, but 7 (31.8%) are imperiled, 3 (13.1%) are vulnerable and only 13 (56.1%) are currently stable (Fig. 11; Table 2). This means, that 44% of the species from the Sabinas River are in some status of imperilment. It is noteworthy that all 7 imperiled gastropods are hydrobioid species

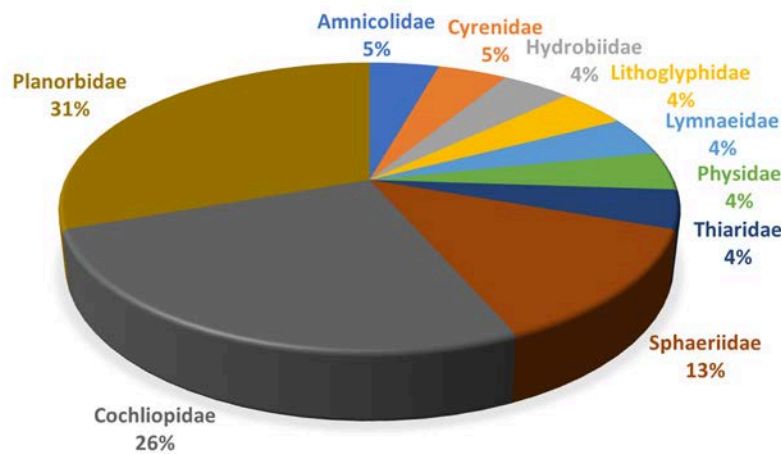


Figure 8. Percentage of freshwater snail families at the Sabinas River.

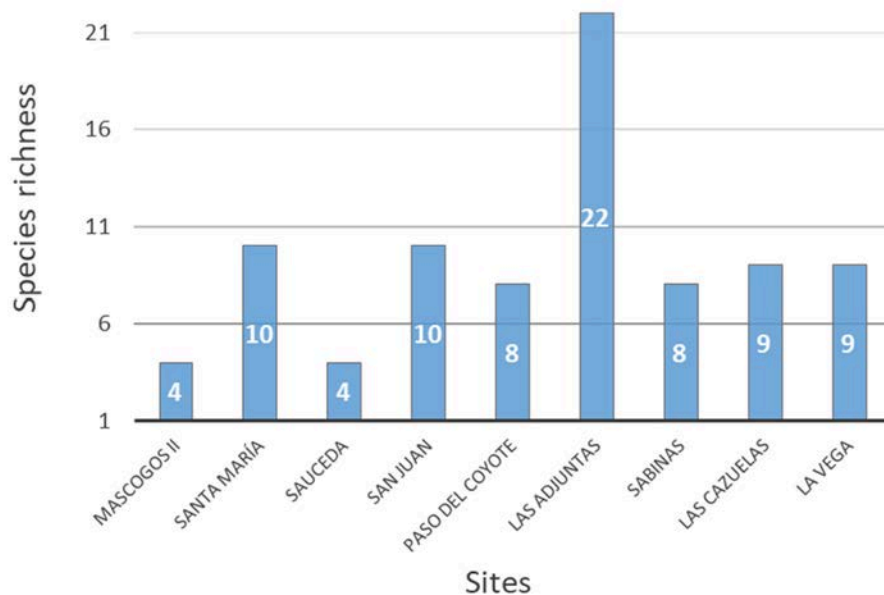


Figure 9. Number of species of molluscs per site in the Sabinas River.

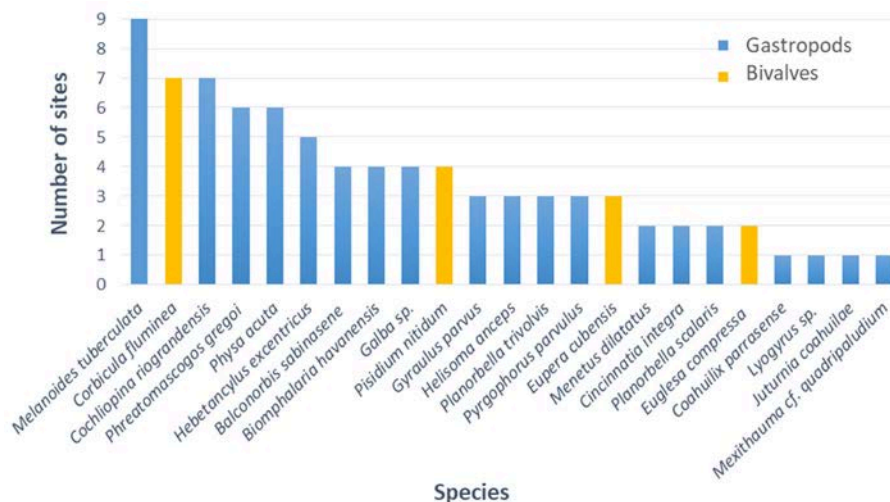


Figure 10. Number of sites occupied by each of the species present in the Sabinas River.

(Cochliopidae, Hydrobiidae and Amnicolidae) and all endemics belong to this imperiled group. This indicates clearly that the hydrobioid snails should be in a special focus of conservation efforts. However, to date only 2 species (*M. quadripaludium* and *J. coahuilae*) are listed as endangered by the Secretaría de Medio Ambiente y Recursos Naturales (Mexican Secretariat of Environment and Natural Resources) (Semarnat, 2010). The locality with the highest number of imperiled species is site 6 (Las Adjuntas), where 5 of the 7 endangered gastropods occur.

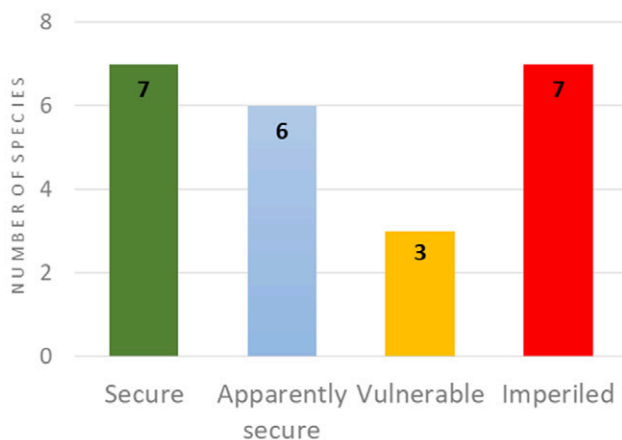


Figure 11. Conservation statuses for the Sabinas River molluscs based on the NatureServe conservation rank system by Master et al. (2012). The numbers within the columns indicate the number of species in each category.

Discussion

Although, so far, only a small part of the Sabinas River and 1 site at the Álamos River were studied, the 23 species of molluscs reported is substantial. No other site in Northern Mexico has a richer record in number of species; including the well-studied Cuatro Ciénegas Basin, where 20 species occur in total. Of the 14 gastropod freshwater families reported in Mexico (Czaja et al., 2020), 8 occur in the Sabinas River, thus, this area can be considered an important refuge for rare species.

Today the Cuatro Ciénegas Basin and the Sabinas River have merely a temporary connection due to the Monclova River, which is an intermittent stream (own observations). Genetic flow between snail populations is at least temporarily limited or does not take place, so that allopatric evolutionary divergence processes in snails are very likely (2 different species of the genus *Coahuilix*). Some species such as *P. gregoi*, *B. sabinasensis*, *C. parrasense* and *Lyogyryus* sp. (not present in Cuatro Ciénegas Basin) developed special habitat adaptations in Sabinas River that limit their distribution to small areas in subterranean environments (Czaja, Cardoza-Martínez et al., 2019). Since it is a lotic environment, the assignment of the individual species to the particular site is fraught with uncertainty. A possible transport of the organisms must be expected.

The assigned conservation ranks imply that at least 10 species from Sabinas River are of special conservation significance (Fig. 11), especially, the recently described subterranean species *P. gregoi*, *B. sabinasensis*, *C.*

parrasense and *J. coahuilae*. Stygobiont snails belong worldwide to the most vulnerable freshwater gastropods (Johnson et al., 2013; Böhm et al., 2020). Also, *Lyogyrus* sp., belongs most likely to the same group and we suspect that this snail lives in Sabinas River in the same subterranean habitat with the mentioned stygobionts.

There are many reports from North America about negative ecological impacts of *M. tuberculata* in invaded systems so that the sole presence of this species should already be an alarm signal (Contreras-Arquieta, 1998; Naranjo-García & Castillo-Rodríguez, 2017). In all study sites, especially those with sandy sediments, the invasive *M. tuberculata* is present. However, in more polluted habitats (sites 8 and 9) with strong agriculture activity we observed that the level of abundance increases. We observed that in such human impacted sites *Melanoides* is more common by simultaneous reduction, or total absence, of hydrobioid snails (Czaja, Covich et al., 2019).

Due to the limited number of samples from different habitats, we did not perform a species abundance analysis, however, in all sites *Melanoides* and *Corbicula* are by far dominant while all other species, especially the hydrobioids (except *Cochliopina*), are rare. Since we have no historical data, we cannot directly prove a positive relationship between the occurrence of *Melanoides* and low densities of the native species. Nevertheless, such a relationship in the Sabinas River is quite likely, considering the many reports from similar sites in northern Mexico (Contreras-Arquieta, 1998). The key point for the native species of the Sabinas River is probably not the sole presence of the invasive forms but the combination with the degree of pollution (eutrophication) of the sites. An aquatic ecosystem can apparently “amortize” an invasion, but with a simultaneous heavy pollution (eutrophication), the less tolerant native forms are disadvantaged.

Like *Melanoides*, *C. fluminea* is also one of the most important invasive species, whose populations underwent massive expansion in a short time, creating negative impacts on native bivalves in many aquatic ecosystems of North America and Europe (Beran, 2006; Ilarri & Sousa, 2012; Sousa et al., 2008). Characteristic of affected habitats with the presence of the Asian clam, is the lack of bivalves of the genus *Sphaerium* Scopoli, 1777, and large unionid mussels. Such displacements of large native bivalves are reported from many sites with *C. fluminea* in North America (McMahon, 2002; Sousa et al., 2008; Vaughn & Hakenkamp, 2001). Such large bivalves are seemingly missing in the Sabinas River, although they are very common in subfossil molluscan assemblages in neighboring areas (Czaja et al., 2014; own observations). So far, *C. fluminea* has not been detected within Cuatro Ciénegas but it does occur just outside of the basin in the

Rio Salado de Nadadores (Dinger et al., 2005). Why *C. fluminea* has not invaded the springs of Cuatro Ciénegas is unclear.

If the heavy human impact downstream continues, we expect further expansion of both non-native species, with strong changes in the native molluscan assemblages for the Sabinas River area, especially bivalves. Because biological invasions are generally irreversible (Vander-Zanden & Olden, 2008), the implementation of management actions is urgent, such as monitoring, further research on the invasive species, identifying their undesired consequences and the determination of site vulnerability. However, the first step in this process must be the integration of the mentioned 7 imperiled species from the Sabinas River into the list of NOM-059 of the Secretaría de Medio Ambiente y Recursos Naturales (Mexican Secretariat of Environment and Natural Resources) (Semarnat, 2010).

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