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Discovery of an established population of a non-native species of Viviparidae (Caenogastropoda) in Argentina

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Abstract

Discovery of an established population of *Sinotaia quadrata* (Benson, 1842) in a river and reservoir in Argentina is reported, representing the first report of a Recent viviparid species in South America. Viviparids are a family of freshwater snails occurring nearly worldwide. A study of the shell and aspects of the anatomy of *S. quadrata* are presented. It is distinguished from other native taxa by its large shell size, presence of a blackish axial band on the columellar side of the aperture and two to three carina on the body whorl. The invasive species *Physa acuta* Draparnaud, 1805 (Physidae) and *Corbicula fluminea* (Müller, 1774) (Corbiculidae) also inhabit the same sites as *Sinotaia quadrata*. Co-occurring native species of molluscs are *Pomacea canaliculata* (Lamarck, 1822) (Ampullariidae) and *Biomphalaria tenagophila* (d´Orbigny, 1835) (Planorbidae). This record increases the total number of invasive gastropods in Argentina to six.

Key words: Mollusca; Gastropoda; Architaenioglossa; freshwater snail; *Sinotaia quadrata,* South America, Gastropoda, invasive species.

Introduction

The introduction of alien species is presently one of the most serious challenges for the protection of natural ecosystems (e.g., Karatayev *et al.* 2009a). It is well known that invasive species result in global homogenization of communities, altering the once distinctive regional biota, and affecting ecosystems through competitive exclusion of indigenous biota (Cowie 2001, 2005). This work reports the establishment of *Sinotaia quadrata* (Benson, 1842) in Argentina, which constitutes the first record of a living viviparid in South America. The Viviparidae are a moderately large family of operculate freshwater snails occurring nearly worldwide in temperate and tropical regions that, except as fossils, are absent in South America (Prashad 1928; Parodiz 1969; Starobogatov 1992; Strong *et al.* 2008). Prashad (1928) reported two fossil viviparids in South America, *Viviparus wichmanni* Doello Jurado, 1927 from the upper Cretaceous of Rio Negro (Argentina) and *Paludina araucana* Philippi, 1887 from the Tertiary of Chile. These two records indicate that the viviparids lived in South America from at least the upper Cretaceous to early Tertiary. Prashad (1928) suggested that marine flooding of the areas in which the family flourished was responsible for the disappearance of the family from the freshwater fauna. Later, Parodiz (1969) cited the presence of the genus *Lioplacodes* Meek & Hayden, 1864 with five fossil species inhabiting different parts of South America. *L. ferugloi* Parodiz, 1969 and *L. wichmanni* Doello Jurado, 1927 from Rio Negro province, Argentina; *L. lacerdae* (Hartt, 1870) and *L. williamsi* (Hartt, 1870) from Bahia, Brazil and *L. bolivianus* Parodiz, 1969 from Potosi, Bolivia. Parodiz (1969) also stated that *Lioplacodes* became extinct in South America early in the Tertiary.

Viviparidae is a family group generally characterized as being dioecious, ovoviviparous and sexually dimorphic. The taxonomy of Viviparidae is mainly based on shell morphology and the characters used are mostly shell shape, size and sculpture. However, species are difficult to differentiate due to overlap of shell characters, product of the high intraespecific variability. The majority of Recent and fossil species of Viviparidae were originally described in the genera *Viviparus* Montfort, 1810 and *Paludina* Lamarck, 1812. The family is now subdivided into three subfamilies, Lioplacinae Gill, 1863 (=Campelominae), Bellamyinae Rohrbach, 1837 and Viviparinae Gray, 1847 (Bouchet and Rocroi 2005). According to Sengupta *et al.* (2009) the African, Asian and Australian genera all belong to the subfamily Bellamyinae and all European genera to the Viviparinae but the genera from North America include representatives of the three subfamilies. Yen (1943) made a revision of the Chinese viviparids formely included into *Viviparus*. Haas (1939) described *Sinotaia* (type species *Paludina quadrata* Benson), as a subgenus of *Taia* Annandale, 1918. *Sinotaia* was originally classified in Viviparinae (=Paludinidae Fitzinger, 1833) and according to Haas (1939) comprise the Chinese species formerly attributed to *Viviparus* Montfort, 1810, which group around *Paludina quadratus* and *P. angulatus* Lea, 1844.

Sinotaia quadrata is naturally distributed in China, Korea and Taiwan (Lee 2009) and has expanded its native range to other Asian countries such us Japan, Thailand and Philippines. *S. quadrata* is frequently found in the mud or silt of lakes, ponds, rice paddies, irrigation canals and streams. In Taiwan, this species is known to be a host of the metacercariae associated with echinostomiasis, a food-borne, intestinal, zoonotic, snail-mediated parasitosis caused by these digenean trematodes of the family Echinostomidae

(Graczick and Fried 1998). Other viviparid species native to Asia that have invaded many areas of North America are *Bellamya* (*Cipangopaludina*) *japonica* (von Martens, 1861) and *B.* (*Cipangopaludina*) *chinensis* (Reeve, 1863). These species are currently classified into the subgenus *Cipangopaludina* according to Smith (2000). Both taxa, and the influence of *B. chinensis* on the distribution and abundance of native snail assemblages of species, has been extensively documented (Johnson *et al.* 2009; Karatayev *et al.* 2009b; Solomon *et al.* 2010).

In Argentina, the native freshwater snail fauna is composed of 101 species, 53 of which belong to operculate groups Ampullaridae, Thiaridae, Cochliopidae and Lithoglyphidae. Five alien freshwater gastropods are also known, including a single operculate species, *Melanoides tuberculata* (Müller, 1774) (Rumi *et al*. 2008). Introductions in Argentina are suspected to have occurred in different ways but human transport and the aquarium trade are the most probable routes of entrance (Gutierrez Gregoric *et al.* 2007). The goals of the present research are to report the first record of an alien viviparid species in South America, specifically in Argentina; to provide a description of its anatomy due to the lack of previously published information existing on this species and to highlight the possible effects of the impacts of an invader species at the community level.

Material and Methods

Live specimens of *Sinotaia quadrata* were first located in October 2009 in the Grande de Punilla River, Punilla valley, Cordoba Province in central Argentina (Fig. 1A, B). The first place where the snails were found was at the tourist development Complejo Siete Cascadas (31º05'49.0" S 64º30'08.4" W) (Fig.1 C, site 4). Field work in the area in February 2010 and November 2010 involved searching for specimens in nearby locations. The Grande de Punilla River crosses the village La Falda (S 31º 05' 22.55" W 64º 28' 58.52", at 934 m. altitude) where a dam was constructed (Fig. 1C). The La Falda reservoir with a volume of 800.000 m³ of water has an important role as water resource for the village, plus nautical and fish activities. The Grande de Punilla River has a marked seasonality with strong floods in summer and low water level in winter. During November 2010, this river was surveyed 3 km upstream (Fig. 1 C, sites 5, 6) and 15 km downstream to the south of the reservoir (Fig. 1 C, sites 4, 7-10) from S 31º 05' 19" W 64º 30' 9" to S 31º 11' 39" W64º 28' 32.9". Three other sites in La Falda reservoir were also examined (Fig. 1, sites 1–3). *S. quadrata* were found only in the reservoir (sites 1–3), and no further than 3 km to the south of the dam in the river (sites 4, 8). Live specimens were absent to the north of the reservoir (sites 5, 6), and in the Quinteros stream (site 7) that crosses La Falda village. No living snails were found further downstream from Valle Hermoso village (Fig. 1 B). In each site of occurrence, ten adult snails of *S. quadrata* were collected and water conductivity and pH were also recorded at each site.

Shell measurements (total length, maximum and minimum shell diameter) were taken using a caliper under a dissecting microscope. Specimens for morphological studies were relaxed in menthol crystals in water for 24 hrs and then transferred and fixed in 96% ethanol. The extraction of the body from the shells was easily done, uncoiling the body without breaking their shells. Adult and juvenile specimens were examined using a binocular microscope. Three to ten adult specimens were dissected to describe each organ system. Drawings were made with the aid of a *camera lucida*. The radula was extracted from the buccal mass and and examined together with the shell using a Jeol Scanning electron Microscope 35 CF. Terminology used in morphological descriptions followed Simone (2004). Type material of *Sinotaia quadrata* was found at the National History Museum of the United Kingdom (NHMUK). Voucher material of the molluscs collected is deposited in the Instituto-Fundación Miguel Lillo (IFML15551-15558) malacological collection in Tucumán, Argentina and in Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina (MACN-In 39245).

Results

Systematics
Class **Gastropoda**
Caenogastropoda
Informal Group Architaenioglossa
Superfamily Viviparoidea Gray, 1847
Family Viviparidae Gray, 1847
Genus *Sinotaia* Haas, 1939
Type species: *Paludina quadrata* Benson, 1842, original designation.

Sinotaia quadrata (Benson, 1842)

Paludina quadrata Benson, 1842: 487.
Taia (*Sinotaia*) *quadrata*. Haas, 1939: 96.
Viviparus quadratus quadratus.Yen, 1939: 35, pl. 3, fig. 6.
Sinotaia quadrata. Je, 1989: 15; Choe & Park, 1997: 94; Wu, 2003: 64; Wu & Lee, 2005: 15, fig. 29; Lee, 2009: 243, fig. 1.

Type Material:

Probable syntypes: NHMUK1842.9.30.34–44, 12 specimens.

Type locality: China, Chusan Island, canals and ponds (as originally published by Benson 1842).

Other material examined: Argentina, Córdoba, Punilla Dept., La Falda Dam, road to Siete Cascadas, 11/10/2009, leg. X. Ovando (IFML 15551). Punilla Dept., La Falda, Punilla Grande River, 31º05'49''S 64º30'08.4''W, 3/11/2010, coll. X. Ovando (IFML 15552). Punilla Dept., La Falda, Club del Lago, 31º05'43.1''S 64º30'21.5''W, 930 m, 2/11/2010, coll. M. J. Miranda, M. G. Cuezzo & X. Ovando (IFML 15553). Punilla Dept. La Falda, on the Dam, El Lago camping, 31º05'39.7''S 64º30'10.2''W, 944 m, 3/11/2010, coll. X. Ovando (IFML 15554). Punilla Dept. La Falda, Complejo Siete Cascadas, 4/01/2010, coll. D. Dos Santos &

X. Ovando (IFML 15555). Punilla Dept. La Falda, near the bridge in front of Hotel del Lago, 31º05'29.9''S 64º30'16.3'' W, 03/11/2010 , leg. M. G. Cuezzo (IFML 15556). Punilla Dept. La Falda, Complejo Siete Cascadas, 31º05'49''S 64º30'08.4''W, 3/11/2010, coll. X. Ovando (IFML 15557). Punilla Dept., Valle Hermoso, 31º07'01.8''S 64º29'30.9''W, 884 m, 4/11/2010, coll. M. G. Cuezzo & X. Ovando (IFML 15558).

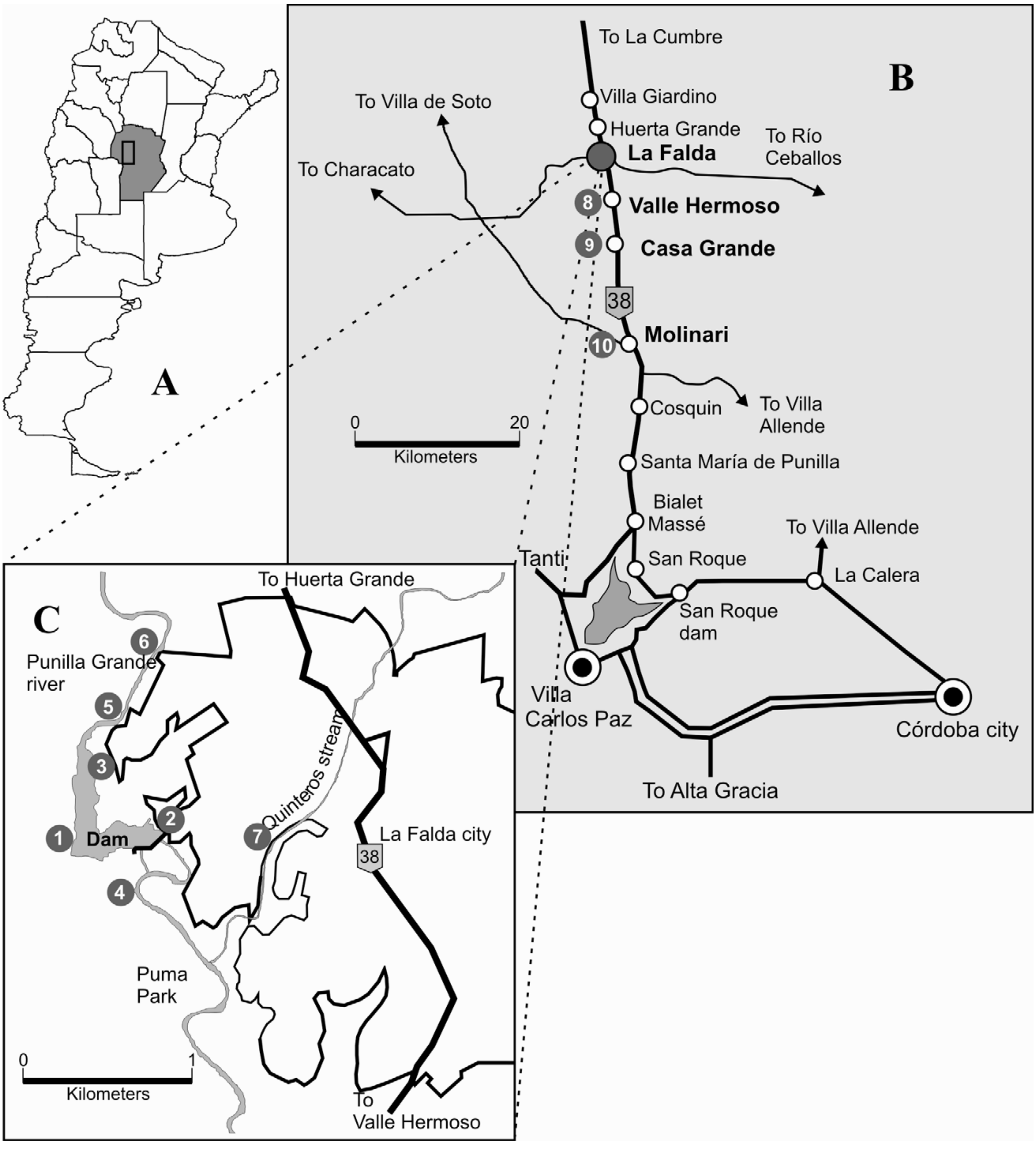

FIGURE 1, Collecting sites of *Sinotaia quadrata* in Cordoba, Argentina. **A.** Map of Argentina highlighting Cordoba province, rectangular area indicating the Punilla Valley. **B.** Detail of Punilla Valley showing the localities surveyed and collecting sites 8-10. Note that white circles indicate villages; dark circles with white numbers inside are the collecting localities. **C.** Detail of La Falda area showing collecting sites 1-7 including the Punilla river and La Falda Reservoir.

Species description:

Shell (Figs. 2–3): Thick, yellowish green or pale brownish, outer margin of aperture blackish, darker on columellar side (Fig. 2A). Some shells with blackish axial band close to aperture. Shell whorls 6 to 7, slightly convex with conic, obtuse spire. Total shell length 25.8–36.6 mm (mean=30.31; sd=3.19) in river (n=20) and 27.9–42 mm (mean= 31.5; sd= 2.97) in reservoir (n=30), maximum shell diameter 18.6–24.1 mm (mean=21; sd=1.60) in river (n=20) and 18.4–27.2 (mean=21; sd=1.68) mm in reservoir (n=30), minimum shell diameter 13.13–15.22 (mean=14.46; sd=0.65) in river (n=20) and 13.24–17.36 (mean=14.58; sd=1.27) in reservoir. Protoconch usually worn out in adult specimens. In juveniles, protoconch with two to four spiral raised lines bearing triangular, thin hairs (Fig. 3A). Between the spiral lines axial wrinkles are marked (Fig. 3B). General shell sculpture with axial growth lines on first whorls becoming thicker and regularly arranged towards body whorl, with low spiral carina (Fig. 2B, C). Suture separating each whorl well marked and deep, thin brownish band visible

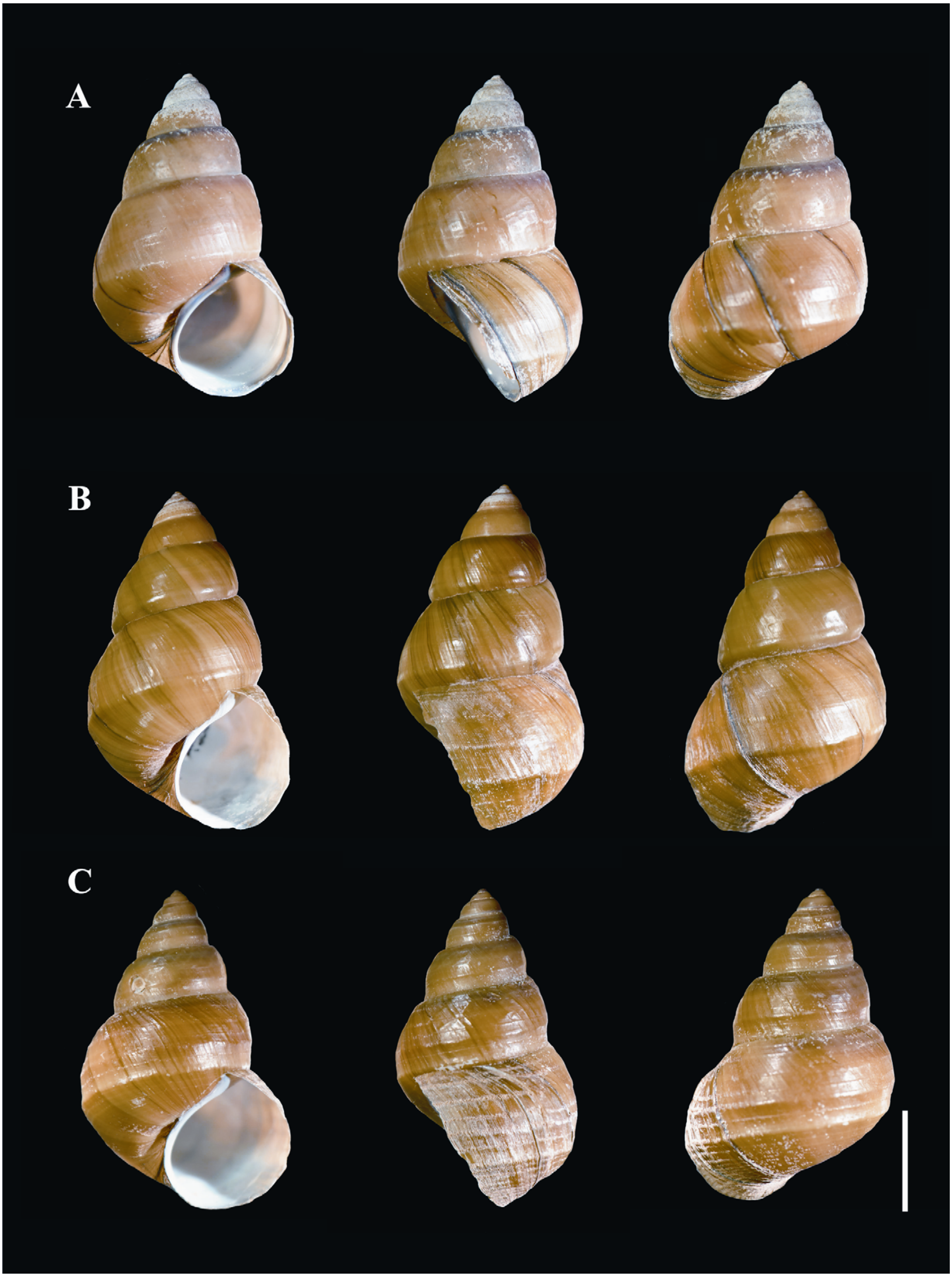

FIGURE 2, Shells of *Sinotaia quadrata* collected from the river and reservoir, each row corresponding to the same specimen. **A, B.** River in Complejo Siete Cascadas, La Falda, IFML 15551. **C.** La Falda reservoir, IFML 15553. Scale bar: 10 mm.

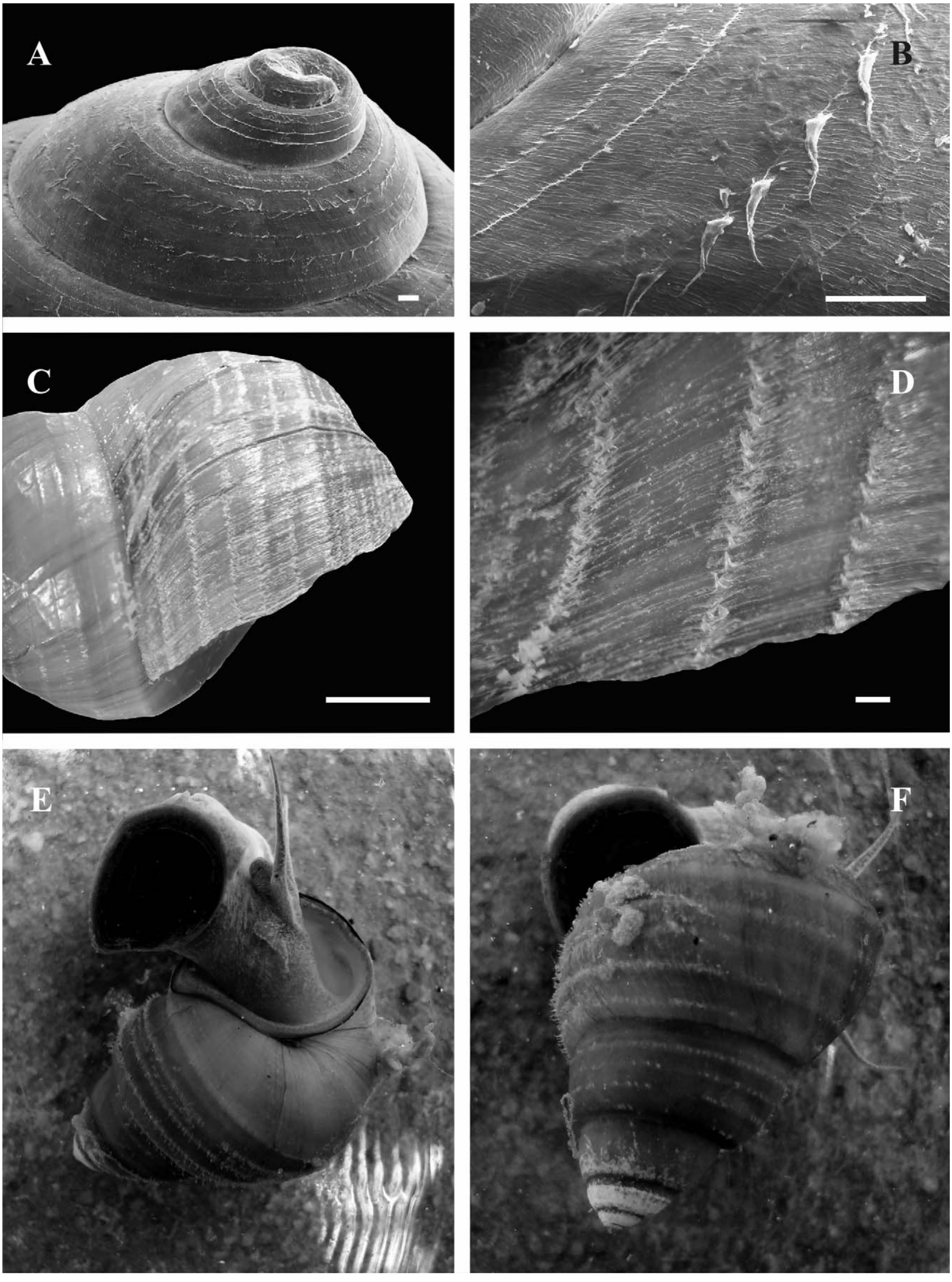

FIGURE 3, Shell sculpture of *Sinotaia quadrata*. **A.** Micro sculpture of Protoconch and first whorl in a juvenile shell; **B.** Detail of the first whorl showing periostracal hairs in a juvenile shell; **C.** Detail in lateral view of body whorl with spiral lines and axial wrinkles; **D.** Detail of body whorl in a subadult showing spiral rows with triangular lamellae, between each row note axial raised lines more regularly arranged than in first whorls. **E, F.** Living subadult specimens showing spiral keels and spiral rows with triangular lamellae. Note that first whorls are worn away. Scale bars: A, B 100 µm, C 5 mm, D 0.5 mm.

below suture on spire. Body whorl with two to three spiral keels on upper, middle, and lower part (Fig. 2B, C). Between keels other low, thick spiral lines visible sometimes bearing triangular lamellae. These lamellae are lost or worn out in adult shells giving an appearance of raised spiral lines. Shell base below lower keel with minute triangular lamellae regularly arranged in several thin spiral rows (Fig. 3C, D). Juveniles show several spiral lines bearing long periostracal thin hairs with triangular base in spire. Periostracal hairs lost in adults. Shell aperture subcircular with length slightly greater than width.

Head-foot (Fig. 4) (description partly based on living material): Head slightly protruded when crawling. Snout cylindrical with anterior margin flat. Long tentacles about two times longer than snout. Ommatophore short located at outer surface of each tentacle. Adult males identified by modified right tentacle, a stout, truncated structure serving as a copulatory organ (Fig. 4A). Pair of siphons (nuchal lobes) rounded, short (Fig. 4B). Food groove ending in right nuchal lobe dividing it into two projections with anterior, dorsal projection close to base of snout (Fig. 4C). Foot large with simple sole. Operculum in dorsal foot surface with outline circular, edges projecting beyond it, occupying entire shell aperture; sculptured with concentric growth lines with nucleus subcentral closer to inner margin. Columellar muscle thick, length about ¾ whorl (Fig. 4A, B).

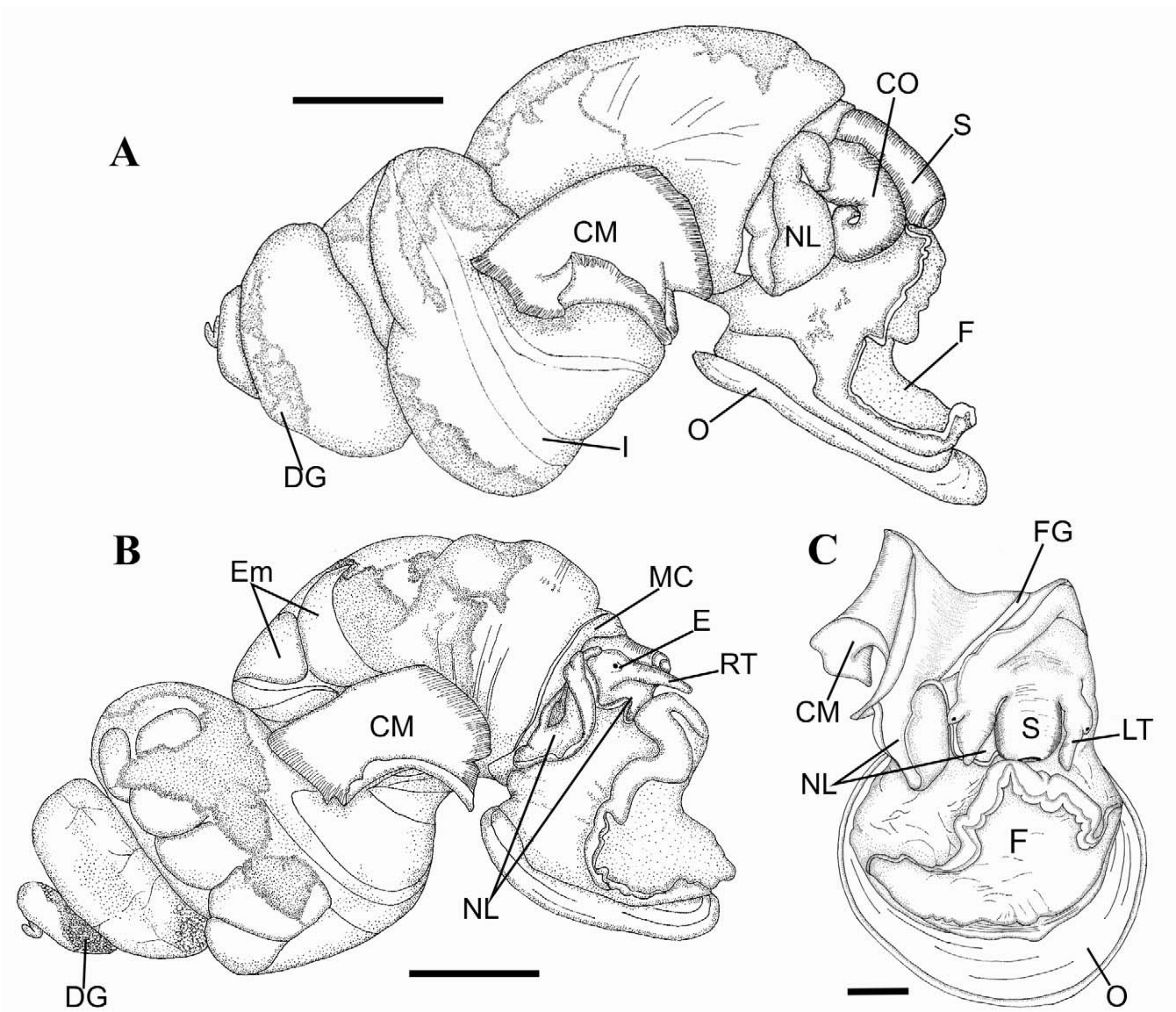

FIGURE 4, *Sinotaia quadrata* male and female lateral views without shells. **A.** Male specimen showing copulatory organ in right tentacle. **B.** Female specimen showing prominent nuchal lobes and embryos in uterus. Note the shape and size of collumelar muscle. **C.** Detail in frontal view of the adult head showing snout, position of nuchal lobes and food groove. Scale bars: A, B, 5 mm, C, 2 mm. Abbreviations: CM— collumelar muscle; CO— copulatory organ; DG— digestive gland; E— eye; Em— embryos; F— foot; FG— food groove; I— intestine; LT— left tentacle; MC— mantle collar; NL— nuchal lobe; O— operculum; RT— right tentacle; S— snout.

Pallial system (Fig. 5): Mantle cavity of about one whorl. Mantle border simple, smooth, thick. Osphradium ridge-like, thin, oblique with respect to mantle border, parallel to gills (Fig. 5A). Gill long and narrow bordering left side of mantle cavity, same length, with gill filaments tall and narrow, anterior end at mantle border. Ctenidial vein thin, running along mantle cavity at base of gills. Endostyle consisting of a glandular shallow portion forming ridge behind gill basal margin. Right margin of mantle cavity filled by oviduct in females (Fig. 5B). Rectum running on left side and along mantle cavity parallel to gills. Ureter broad, running along mantle cavity between rectum and oviduct in females (Fig. 5B) and on right margin of mantle cavity in males (Fig. 4A). Three openings at right end of mantle border in females, ureter pore most posterior and anus anterior. Female pore located between anus and ureter pore (Fig. 5B). Anterior portion of kidney close to terminal gills in distal mantle cavity. Auricle connected to ctenidial vein in distal portion to gill. Ventricle posterior to auricle with narrow connection between them.

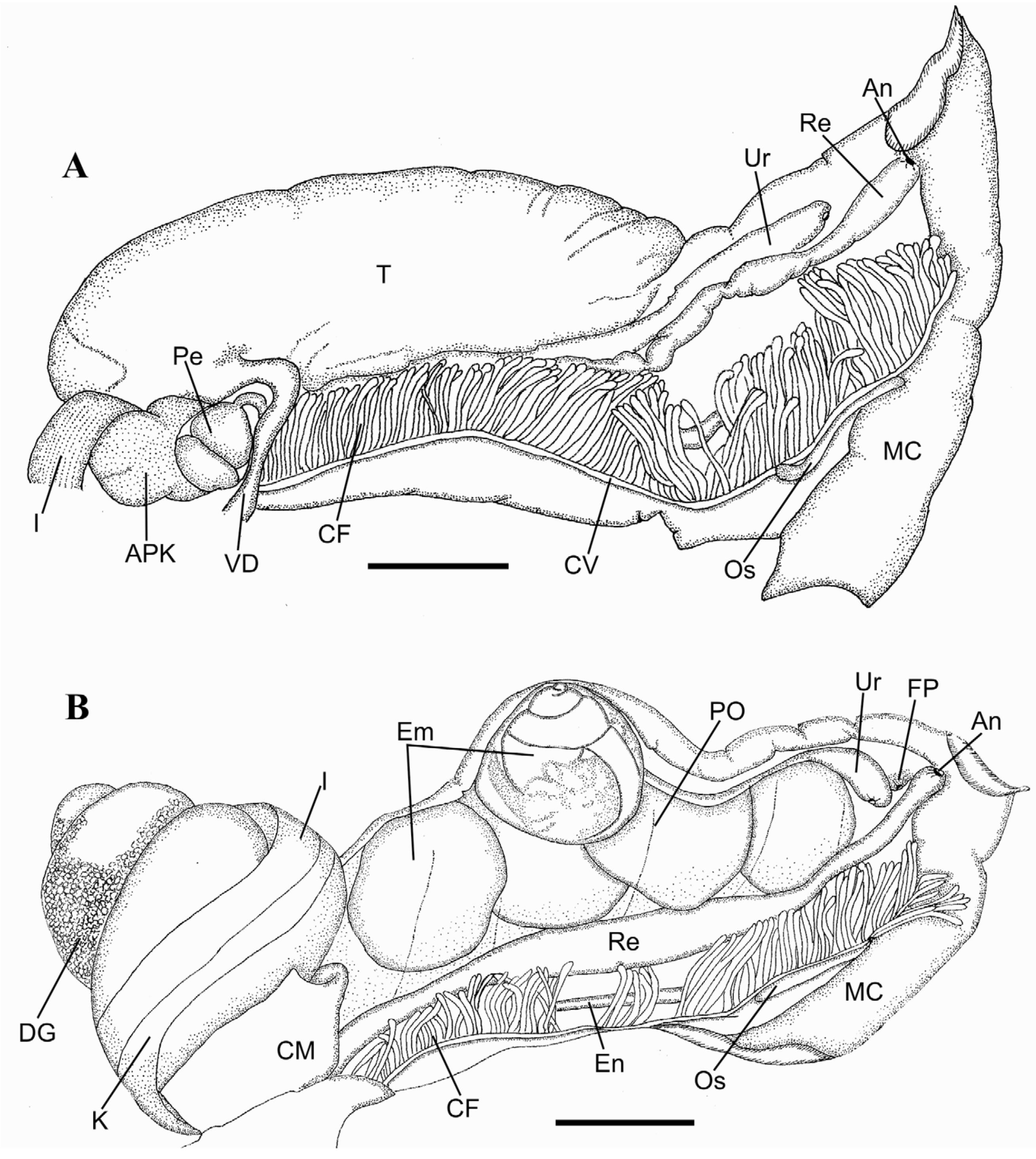

FIGURE 5, Mantle organs of *Sinotaia quadrata*. **A.** Male specimen showing the size and location of testis entering in mantle cavity. IFML 15558. **B.** Female specimen showing pallial oviduct with embryos. Scale bars: A, 3 mm, B, 5 mm. Abbreviations: An— anus; APK— anterior portion of kidney; CV— Ctenidial vein; CM— collumelar muscle; CF— ctenidial filaments; DG— digestive gland; E— embryos; En— endostyle; FP— female pore; I— intestine; K— kidney; MC— mantle collar; Pe— pericardium; PO— pallial oviduct; Os— osfradium; Re— Rectum; T— testis; Ur— ureter; VD— vas deferens.

Digestive System (Fig. 6): Radula taenioglossate, narrow and long (Fig. 6A). Rachidian tooth broad with rectangular central cusp with curved tip, 5 - 6 triangular lateral cusps (Fig. 6B). Two lateral teeth per row, tall, elongated, curved over rachidian, multicuspid. Central cusp of lateral teeth wide and rounded. Two pairs of marginal teeth per row; inner marginal teeth taller than outer marginals, similar in shape to lateral teeth, with central cusp more triangular than in lateral teeth. Outer marginal teeth thin, multicuspid, lacking central broad cusp (Fig. 6C).

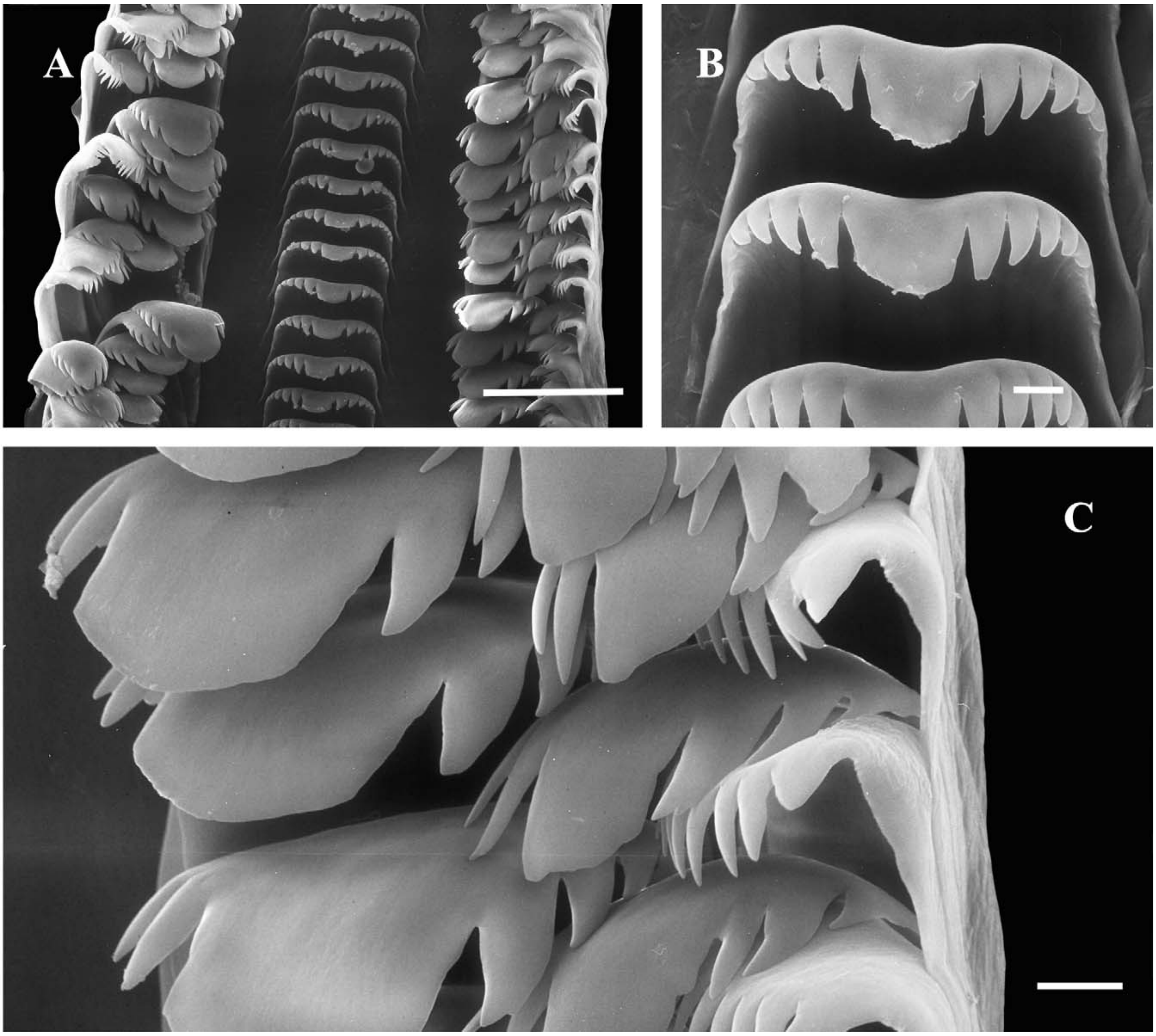

FIGURE 6, Digestive system of *Sinotaia quadrata*. **A-C**. IFML 15557. **A.** General view of radula. **B.** Detail of raquidian tooth with central rectangular cuspid. **C.** Detail of lateral and marginal teeth. Scale bars: A, 100 µm, B, C, 10 µm.

Genital system (Figs. 5, 7): Male: Testis in male specimens large and curved, lies on columellar surface of visceral whorls surrounding columellar muscle and extends over half the length of mantle cavity (Fig. 7). Vas deferens thick, short, running on ventral margin of testis. In pallial cavity, vas deferens surrounded by thick muscular coat attached to columellar muscle, and opens to large prostate gland. Prostate gland closed tube running along pallial cavity floor. Ejaculatory tube long muscular portion of vas deferens penetrating right tentacle, inner surface with low folds. Vas deferens opens at tentacle tip. Right cephalic tentacle thick, modified as copulatory organ.

Female: Visceral oviduct runs along columellar. Pallial oviduct large occupying half of pallial cavity. Ventral chamber of oviduct functioning as large brood pouch filled by twenty to thirty capsules (Fig. 5B). Each capsule covered by membrane. Vaginal tube with thick, muscular walls as continuation from brood pouch. Female genital pore small, close to mantle border (Fig. 5B).

Species Remarks

The species type locality, the island of Zhoushan, formerly transliterated as Chusan, is part of a group of islands located in eastern China. *Paludina quadrata* was collected by Theodore Cantor, M.D. who was member of the Bengal Medical Service and sent as naturalist in a British expedition. Probably he gave the molluscs collected in the island to W. Benson for taxonomic identification. Benson was at that time a member of the Bengal Civil Service. The W. H. Benson collection is currently located in the University of Cambridge Museum of Zoology and also in the Natural History Museum in London (J. Ablett, personal communication). A lot of twelve specimens collected by Cantor in 1842 were found in the Benson collection but these are not labeled as types. We believe that these specimens, due to their locality, shell size and shape, are the ones used by Benson to describe the species, or are at least part of the original series. No other species type material was found in any other Museum. However, only a subspecies type of *Viviparus quadratus grahami* Chen, 1945 is located at the US National Museum (USNM 334007).

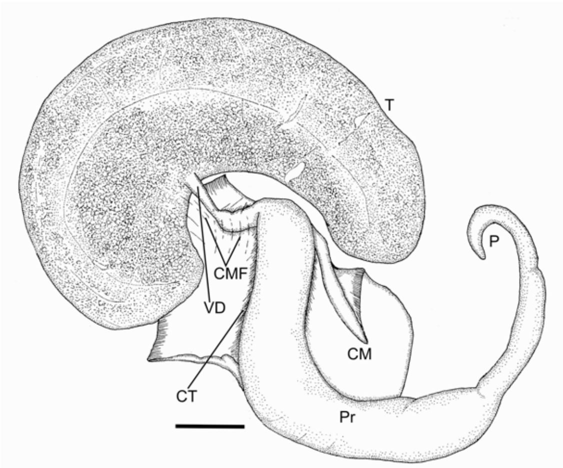

FIGURE 7, Male Reproductive organs of *Sinotaia quadrata*. IFML 15558. Abbreviations: CM— collumelar muscle; CMF— collumelar muscle fibers; CT— connective tissue; P— penis; Pr— prostate; T— testis; VD— vas deferens. Scale bar: 3 mm.

Sinotaia quadrata is clearly different from any other species of freshwater snail living in Argentina. It is very distinctive in its large shell size, the presence of a blackish axial band on the columellar side of the aperture and at least two to three carinae on the body whorl. Shell features such as hairs or lamellae are mostly visible in juveniles and often lost in adult shells. *Sinotaia quadrata* can be readily differentiated at first glance from *Bellamya chinensis* and *B. japonica*, because its shells are solid and narrow with a length no greater than 40 mm (generally most specimens are less than 30 mm), while *Bellamya chinensis* and *B. japonica* are very large (up to 64 mm).

General features of the anatomy of *S. quadrata* are very similar to other viviparids previously described (e.g., see Simone 2004). Gill filaments are very large because they are used for filter feeding, and an endostyle, a glandular ridge parallel to the gill, is normally present in filter-feeding caenogastropods (Simone 2004). As in all Bellamyinae, the testis in *S. quadrata* extends over half the length of mantle cavity while in Viviparinae it lies behind it in the visceral coil (Bourguignat 1862). In some female specimens of *S. quadrata*, as in other viviparid species, embryos were found within the uterus, located in separated capsules of various stages of development. Embryo numbers in uterus of *S. quadrata* varied from ten to almost thirty. Most adult females examined were also gravid specimens.

Study site and taxonomic composition of the molluscan community

The Punilla river has slow moving water with abundant marginal vegetation and in the collecting sites of the river approximately 30-50 % of the water surface was covered by macrophytes (sites 4-6). Live adults and juveniles of *Sinotaia quadrata* were found in the river actively crawling in the benthos, buried in soft substrate or under rocks. River substrate at the collecting sites was composed of soft mud, sand and rocks of different sizes. Density of snails was high under rocks. Altitude at collecting sites ranged from 740 to 950 m above sea level; environmental parameters recorded were pH, which was slightly acid (5-6), and conductivity that was somewhat low (106.2-108.7 µs/cm). During summer the river burst its banks, flooding its margins, and consequently empty shells of *S. quadrata* were found at sites 9 and 10 with no living adult specimens observed at those sites.

Native freshwater molluscs found in the river and La Falda reservoir where *S. quadrata* was collected, are *Pomacea canaliculata* (Lamarck, 1822) (Ampullariidae) and *Biomphalaria tenagophila* (d´Orbigny, 1835) (Planorbidae) plus two other exotic species, *Corbicula fluminea* (Müller, 1774) (Corbiculidae) and *Physa acuta* Draparnaud, 1805 (Physidae) collected only in the river. In La Falda reservoir *Corbicula fluminea*, *Pomacea canaliculata* and *S. quadrata* were the most abundant molluscan species.

Discussion

Sinotaia quadrata population at Cordoba, Argentina can be considered as established since it has occurred there for at least two consecutive years. In addition, juveniles of different sizes have been found in the same place indicating successful reproduction. However, this species has only been living in Argentina for a short time, and no signs of adverse impact were noted. As it is a relatively large snail species and densities can be high, it is probable that negative impact is expected. Solomon *et al*. (2010) suggested that the risk of an invasive species causing ecological change depends on the degree of functional similarity between that species and the native species pool; distinctiveness of the invader enhances its impact on native species and competitors rarely cause extinctions, whereas predators are more likely to do so. *Sinotaia quadrata*, as a member of the Viviparidae has a viviparous reproductive strategy, its brooder capacity retaining their young in brood pouches, ensures its high fecundity and relatively short lifespan (Strong *et al*. 2008). Also, *S. quadrata* has morphological advantages such as its strong, thick shell that can presumably help avoid attack from predators and it can live in water bodies with moderate to low pH and conductivity.

Most of the species inhabiting Argentina are Heterobranchs, which are hermaphrodites, habitat specialists and have restricted geographical ranges. *S. quadrata* is an herbivorous species and its appetite for vegetation may cause a reduction of plant biomass restricting natural microhabitats of native species. Benthic communities can also be impacted by the presence of a viviparid species by altering algal biomass, algal species composition and nutrient cycling (Johnson *et al*. 2009). Viviparids are ctenidial suspension feeders (Ponder *et al.*2008; Strong *et al.* 2008), one of the dominant feeding modes of freshwater macroinvertebrate invaders around the world (Karatayev *et al*. 2009a). This may indicate that *S. quadrata* is much more likely to become established in new waterbodies than any other feeding types species.

The interaction of *S. quadrata* with the native species inhabiting the Punilla River in Cordoba is now difficult to predict. It has been reported that *Bellamya chinensis* caused substantial declines in the growth and abundance of native snails (especially *Physa* and *Lymnaea*) in experimental conditions (Johnson *et al.* 2009). Other works on *Bellamya chinensis* in the field report that this species has negatively influenced population sizes of Planorbidae and Lymnaeidae in North America at a local scale of site probably due to competition for food (Solomon *et al*. 2010).

Pomacea canaliculata is a native species co-existing with *S. quadrata* at the same places in the Punilla River in Argentina. While the interactions of *Pomacea canaliculata* as an invader in China with *S. quadrata* have been extensively studied (Kwong *et al.* 2009), in Argentina the role of both species is inverted because *Pomacea* is the native and *Sinotaia quadrata* is the invasive species. In China, *P. canaliculata* caused significant mortality in early stages (eggs/neonates) of *S. quadrata* and other native species. It will be interesting to test the future interactions of both species.

In Argentina, *Melanoides tuberculata* is the single operculate exotic freshwater species that has previously been recorded as an invader. In two years after its introduction this species has colonized the Yaciretá dam area becoming the dominant mollusc. Before the dam filled, the area was inhabited by three native species of *Aylacostoma* Spix, 1827 (Thiaridae) now extinct in their natural habitats (Quintana *et al.* 2001). *M. tuberculata* has also invaded other countries in South America such as Brazil, Uruguay, Peru, Ecuador, Colombia, Chile, Paraguay and Venezuela. In Peru, *M. tuberculata* competed with and displaced or diminished populations of pulmonate gastropods such as *Lymnaea viator* (d´Orbigny, 1835) and *Helisoma peruvianus* (Broderip, 1832) (Iannacone 2006).

Pulmonate alien gastropod species ocurring in Argentina belong to the families Lymnaeidae, Physidae and Planorbidae (Rumi *et al.* 2008). Among them, *Physa acuta* is the most widely distributed. Its adaptability to changing environments, high proliferation rates, ability for passive dispersal and high tolerance to polluted water enhance its invasive capacities (Albrecht *et al.* 2009). *P. acuta* is also an invasive species in Brazil, Bolivia and Chile as well as in many other parts of the world. Understanding the impacts of an invader species at the community level is important for researchers and managers interested in conserving species diversity. We know little about how the effects of individual invaders may be attenuated or amplified as a result of interactions with other invaders, making the net consequences of biological invasions difficult to predict.

The impact of the introduction of exotic operculate gastropods such as *Melanoides tuberculata* in different countries of South America has been more detrimental to native species in particular than the introduction of exotic pulmonate species. Thus, the invasion of *Sinotaia quadrata* in Argentina needs to be carefully monitored in the future and the impact of its introduction evaluated at a community level.

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