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Revision of the type specimens of *Diplodon ellipticus* and *Diplodon expansus*

(Bivalvia, Unionoida, Hyriidae)

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We redescribe type specimens of two freshwater mussels from Brazil, *Diplodon ellipticus* Spix in Wagner, 1827 and *Diplodon expansus* (Küster, 1856), focusing on previously unnoticed diagnostic conchological aspects in a brief taxonomical review. The first species, represented by one shell previously considered to be lost, was recently rediscovered in the collection of the Zoologische Staatssammlung München, Germany, and identified as the figured holotype. Material of the second species, deposited at the Charpentier Collection at the Musée de Zoologie Lausanne, Switzerland, was discovered to be a syntype series. The lectotype and paralectotypes of *D. expansus* were selected.

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Introduction

Diplodon Spix in Wagner, 1827 is a genus of South American Hyriidae (Bivalvia: Unionoida) characterized by a shell outline varying from elliptical to rhomboid, but never triangular, without wings and presence of umbonal sculpture. The hinge is usually composed by two cardinal teeth and one lateral tooth on the right valve, and one cardinal tooth and two lateral teeth on the left valve. All species have a glochidium-type larva. Most species of this genus are known only from old conchological studies based on drawings of eroded shells. Some important diagnostic criteria like the shape and number of bars of the umbonal sculpture and details of the periostracum were not described or mentioned in those first descriptions. The lacking description of these characters and others on the internal surface, in addition to the paucity of detailed illustrations and biological information impede species identification and assessment of the true number of species within the genus.

Two species with the above mentioned taxonomical problems are *Diplodon ellipticus* Spix in Wagner, 1827 and *Diplodon expansus* (Küster, 1856). Haas (1931, 1969a) observed that *D. ellipticus* is one of most misunderstood species and states that this name is used for all elliptical forms of *Diplodon* with little ornamentation. Simpson (1900, 1914) makes a comment about *D. expansus*, which clearly shows the state of knowledge about this species: "I know nothing of this. It looks more like an Australian than a South American form, and quite likely a *D. australis*". Taking into account that the type material of *D. ellipticus*

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Fig. 1. Set of labels found associated to the lot identified as supposed type material of *Diplodon ellipticus* at the malacological collection of the Zoologische Staatssammlung München (ZSM Mol. 20120179), by Fechter (1983) and Nutall (1990). **A.** Old label, unidentified. **B.** Green label of Kriechbaumer, old director of ZSM (Fechter 1983). **C.** Two labels of H. Modell. **D.** Label from C. P. Nuttall.

was until now considered to be lost (Nutall 1990), that the type of *D. expansus* was never revised, and that proper knowledge about type specimens is essential for a correct identification, the aim of this work is to appropriately describe the shells of these two species in order to improve the knowledge about the genus *Diplodon* and to provide a basis for future revisions of the genus.

Taxonomy

Diplodon ellipticus Spix in Wagner, 1827

Brief taxonomic review of the species and type material

For a period of three years (1817–1820), Johann B. von Spix and the Botanist Carl F. P. von Martius traveled through Brazil, collecting molluscs as well as other zoological, botanical, geological and anthropological material. According to Fittkau (2001) and Cowie et al. (2004), Spix died soon after coming back to Germany, leaving unfinished the descriptions of the molluscs found in Brazil. The mission to finish this work was given to J. A. Wagner, who published it in 1827, one year after Spix died (Fittkau 2001). This joint publication in which drawings, preliminary species names and a short diagnosis were contributed by Spix whereas new species names and a more complete description of species was suggested by Wagner (Fittkau 2001, Cowie et al. 2004), led to many doubts about species authorship. Here, we follow a solution for authorship with respect to all species and genera described in Wagner (1827) proposed by Cowie et al. (2004): the authorship of most species should be attributed to Spix, and the book itself should be credited to Wagner.

Diplodon was proposed by Spix in Wagner (1827), without a formal description and type designation. Later Simpson (1900) designated *Diplodon ellipticus* as the type species of the genus. The characteristics given by Wagner (1827) in the short description of this species have been used for the diagnosis of the genus *Diplodon* s. s. According to Spix in Wagner (1827), two figures represent in full-scale the external view of one valve and the internal view of both valves. However, the drawings are mirrored; the right valve appears as left valve and vice-versa (Ihering 1890, Cowie et al. 2004). The description of the shell by Wagner (1827) is also reversed. Details of the umbonal sculpture were not presented in drawings or in the text (Wagner 1827). Simpson (1900) created a new name for *Unio ellipticus* Wagner, 1827, *Diplodon wagnerianum* Simpson, 1900, arguing that the previous name was already occupied. Ortmann

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(1921) claimed that the new name proposed by Simpson (1900) was unwarranted. He argues that Spix assigned the species name in connection with the generic name. Therefore, if the generic name is valid, the specific name must be maintained. Ortmann (1921) considered *D. ellipticus* as a poorly known species, but valid, and the description and the drawings of Ihering (1890) as the better description of the species. Several authors mentioned the species as valid (Mansur 1970, Mansur & Pereira 2006, Simone 2006, Graf & Cummings 2007). Haas (1931, 1969a) allocated *D. ellipticus* as a subspecies of *Diplodon granosus* (Bruguière, 1792). Haas (1969b) presented a picture of *Diplodon ellipticus* that does not resemble the drawings of the original description. Nuttall (1990) asserted that the illustration in Haas (1969b) in fact refers to *Diplodon granosus*.

Type locality

Wagner (1827) mentions only São Francisco River, a very big river that flows over 2863 km from Southeastern to Northeastern Brazil crossing five states (Minas Gerais, Bahia, Pernambuco, Sergipe and Alagoas) until it reaches the Atlantic Ocean (Silva et al. 2003). According to the travel journal of Spix and Martius (1938), they crossed the São Francisco River in the states of Minas Gerais, Bahia and Pernambuco at three points: Porto do Salgado (now Januária, Minas Gerais), Caninanhas (border of Minas Gerais and Bahia) and Juazeiro (border between Bahia and Pernambuco). But based on the information of the travel journal it is impossible to specify the locality where the specimen was collected.

Fechter (1983) affirmed that the type locality is the São Francisco River in the state of Minas Gerais. Nuttall (1990) gave "Rio São Francisco, eastern Brazil" as the type locality and indicates "Minas Gerais Province" in the caption of his figure. Neither of the two authors explains why they chose São Francisco River in the state of Minas Gerais as a possible type locality.

Table 1. Measurements of "types" of *Diplodon ellipticus* assigned by different authors. Fechter (1983) and Nuttall (1990) gave measurements for two shells. All measurements are in millimetres. * not measured by Wagner (1827)

	Length	Height	Width
Drawing of Spix in Wagner (1827) and Ihering (1890)	48	26	15*
Fechter (1983)	49.6	30.5	17
	39.1	25.4	14
Nuttall (1990)	49.3	31.0	16.9
	38.8	25.0	14.1
This work	47.70	25.75	15.10

Previous revisions of the Spix collection

The Spix collection housed at the Zoologische Staatssammlung München (ZSM; Munich, Bavaria, Germany) was revised by Ihering (1890) and Fechter (1983), but some questions about the identity of *D. ellipticus* still remained (Nuttall 1990). Ihering (1890) presented a description of the type specimen including drawings of the internal view of both valves and measurements. He also presented a detailed description of the type and some comments about taxonomy. Ihering (1890) claimed that he examined the original material of Spix, and that his measurements agree with those of Wagner (1827). Fechter (1983) revised and presented specimens with different shell outlines and measurements compared to those of Wagner (1827) and Ihering (1890). Based on the shape table for the outlines of mussels in Mansur & Pereira (2006), we conclude that the original *D. ellipticus* has an elliptical-lanceolate outline, whereas Fechter's (1983) specimens have an ovoid outline. Another important difference is that Ihering (1890) mentioned the existence of only one type specimen, while Fechter (1983) mentioned two syntypes. In the collection of the ZSM, the lot labeled as type of *Diplodon ellipticus* (ZSM Mol. 20120179; Fig. 1) is the one used by Fechter (1983) and Nuttall (1990) and is composed of two shells (four valves) with different sizes (Fig. 2). Fechter (1983) illustrated the bigger one (external and internal view), while Nuttall (1990) shows both (external and internal view). Both authors did not elect a lectotype and revealed doubt about the authenticity of the supposed types remarking that their shell measurements did not agree completely with those of Wagner (Table 1). Inside the box of the supposed types there are two handwritten annotations from J. J. Parodiz (undated) and M. C. D. Mansur (written in 2003) noting that these samples are not the correct type material of *D. ellipticus*. Fechter (1983) affirmed that Ihering (1890) was the last who undoubtedly saw the type of *D. ellipticus*, an opinion shared by Nuttall (1990) and Cowie et al. (2004).

Type material of *Diplodon ellipticus*

In the same drawer of the lot presented by Fechter (1983) and Nuttall (1990), there was another lot identified as *Diplodon (D.) charruanus* (d'Orbigny, 1835) (ZSM Mol. 20120180; Fig. 3) with different labels indicating the locality of St. Carlos, Cartago, N. Granada (now Venezuela). This must be an error, because *D. charruanus* is common in Southern Brazil and Uruguay, but does not occur in Ven-

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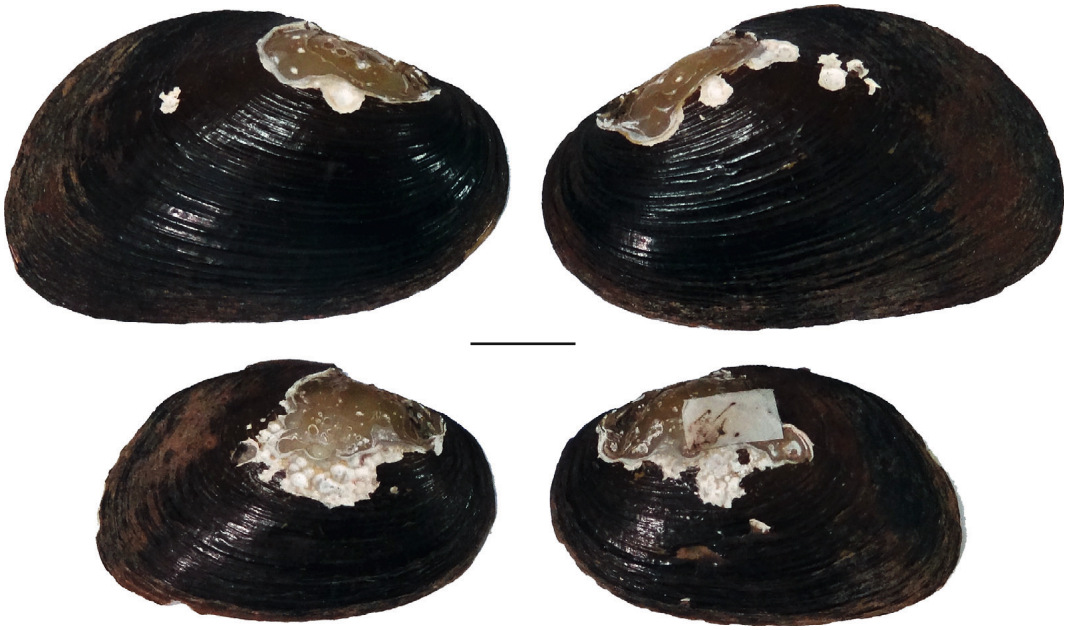

Fig. 2. Shells labeled as type of *Diplodon ellipticus* in the malacological collection of the Zoologische Staatssammlung München (ZSM Mol. 20120179), according to Fechter (1983) and Nuttall (1990). Scale bar = 1 cm. (Photos by I. C. Miyahira).

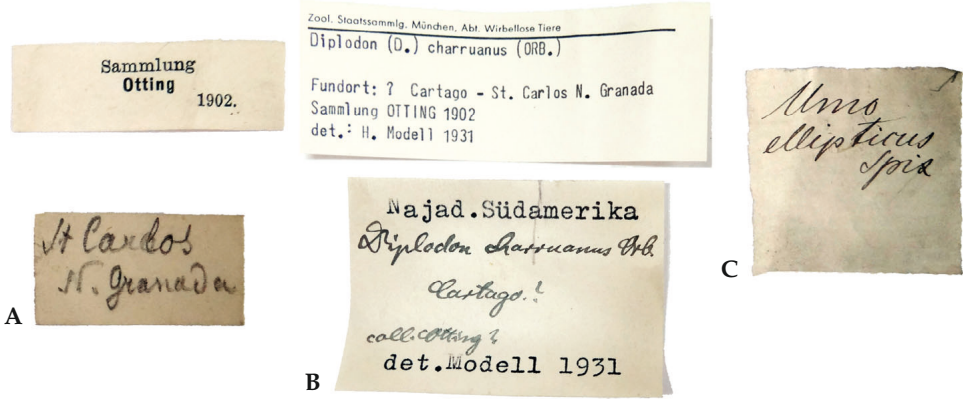

Fig. 3. Set of labels found with the lot identified as *Diplodon (D.) charruanus* (Orbigny, 1835) at the malacological collection of the Zoologische Staatssammlung München (ZSM Mol. 20120180), where the real type of *D. ellipticus* was found. **A.** Labels from Otting Collection. **B.** Labels of Modell identifying the specimen as *Diplodon (D.) charruanus*. **C.** Label with an old fashioned hand writing of "*Unio ellipticus* Spix".

ezuela. However, there is another label on it in old-fashioned handwriting, *Unio ellipticus* Spix (Fig. 3C). The author of this label is undetermined. The lot is composed of one complete shell (Fig. 4A–D). Inside the right valve *ellipticus* is written in pencil with the same old-fashioned letter (Fig. 4E). The inscription is weak and can barely be seen, but certainly the same person wrote on the label and inside the valve. The measurements of this specimen are close to those of Ihering (1890) (Table 1). A comparison between the illustration of Spix in Wagner (1827), Ihering (1890) and our pictures, show an identical outline suggesting that the lot identified as *Diplodon (D.) charruanus* is indeed the lost type material of *Diplodon*

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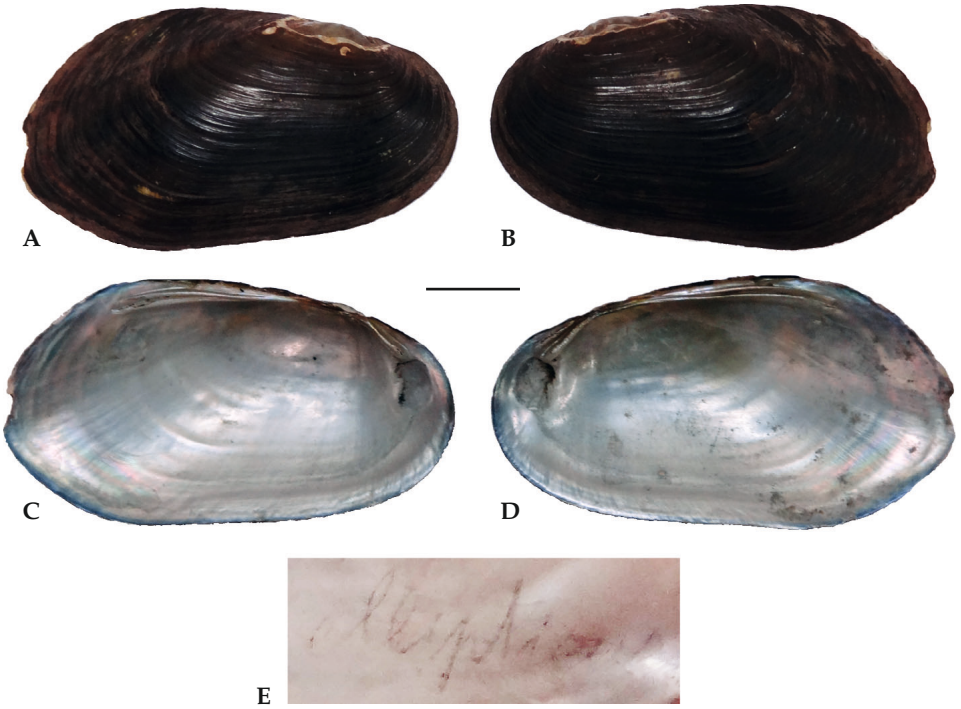

Fig. 4. Holotype of *Diplodon ellipticus* Spix in Wagner, 1827, according to Spix and Ihering (1890) housed at Zoologische Staatssammlung München (ZSM Mol. 20120180). **A.** External view, right valve. **B.** External view, left valve. **C.** Internal view, left valve. **D.** Internal view, right valve. **E.** Detail of the inner side of the right valve with the handwriting name *"ellipticus"* (The colour was changed in order to improve the name wrote in the inner surface of the valve). Scale bar = 1 cm. (Photos by I. C. Miyahira).

ellipticus, and represents the original shell described by Spix.

Redescription of the type specimen of *Diplodon ellipticus*

Basic measurements are listed in Table 1. Outline elliptical-lanceolate. Anterior region lower than posterior. Ventral and dorsal margin somewhat curved, anterior margin regularly rounded, posterior pointed, at a distance of 17.70 mm from the dorsal margin. Posterior ridge double, well-marked. Maximum height 54 % of length. Height at umbones 22.30 mm, or 47 % of the length. Difference between maximum height and umbo height just 3.45 mm. Beak slightly elevated, located at nearly ⅓ of shell length. Shell not inflated; length more than three times the width (width = 32 % of length). Periostracum dark brown, lustrous, concentric folds generally weak and not clear. Umbonal region naturally eroded, umbonal sculpture vestigial: short traces composed of fine radial bars are visible on anterior and posterior ends, without any trace of bars in the center of the umbonal region, three visible anterior bars, slightly curved and pointing backwards, four visible posterior bars, longer than anterior, also pointing backwards. Hypostracum grayish-blue, iridescent. Right valve, two cardinal teeth, slightly crenulated, lower tooth somewhat longer and thicker than upper. Left valve, cardinal tooth lamellar, single with traces of an extremely reduced thin lamella upwards; relative short and narrow interdentum. Two lateral teeth in both valves, very long, equally thin, not crenulated, slightly sinuous, beginning behind the umbones, but upper right lateral tooth shorter anteriorly than the lower, all ending at the same point, dorsally to the posterior muscle scar. Anterior muscle scars clearly delimited, posterior weakly marked. Umbonal cavity shallow.

Taxonomical conclusions and remarks

Comparing the samples presented by Fechter (1983) and Nuttall (1990), with the ones described here, there are considerable differences in shell outline and measurements and the number of "type" specimens as explained above. The true origin of the material used by Fechter (1983) and Nuttall (1990) is also

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unknown. There is a tiny label glued to one of the shells, but it is impossible to see what is written on it (specimen below in Fig. 2). Considering the complete lack of similarities and the many doubts raised as described above, we consider the shells presented by Fechter (1983) and Nuttall (1990) to be unrelated to the species or to the type material of *D. ellipticus*. We suggest that the material revised here is the unique type specimen of *D. ellipticus,* figured by Spix in Wagner (1827) and in part by Ihering (1890), as there are strong similarities in outline, measurements and the presence of double lateral teeth in both valves. According to article 73.1.2 of the International Code of Zoological Nomenclature (ICZN 1999), if the nominal species-group taxon is based on a single specimen, it should be considered the holotype fixed by monotypy.

The simplified umbonal sculpture and the lanceolate outline of *Diplodon ellipticus* are reasons to disconnect this species from *D. granosus* considered subspecies by Haas (1969a). The sculpture of this second species features several grains all over the shell not present on *D. ellipticus*. Due to the details of umbonal sculpture, colour and aspect of periostracum, the type of *D. ellipticus* seems to be similar to *D. dunkerianus* (Lea, 1856), a well described species from the rivers of the southeastern part of Brazil that flow to the Atlantic. Further studies (still in preparation) comparing the morphology of shells and soft parts as well as of glochidia are necessary to confirm this apparent similarity.

There are records of *Diplodon ellipticus* from the state of Bahia, in the North of Brazil to the state of Rio Grande do Sul in the South (Simone 2006). Pereira et al. (2012) suggested that this species occurs in watersheds of the São Francisco River, and of the East Atlantic coastal rivers of Brazil, and raise doubts about its presence in the watersheds of South/Southeast Atlantic coastal rivers of Brazil. It seems unlikely that all these records are really *Diplodon ellipticus,* and the new information presented here may help to clarify this issue.

Diplodon expansus (Küster, 1856)

Brief taxonomic review

Küster (1856) based the description of *D. expansus* on shells from the private collection of Jean Charpentier, now housed at Musée de Zoologie (MZL; Lausanne, Vaud, Switzerland) (Dance, 1966). Küster (1856) provided a brief diagnosis of the species in Latin, followed by a description in German, and a hand-coloured lithograph of the external view of the left valve and a schematic drawing of an outline of the dorsal view (Plate 43). The figured specimen is eroded dorsally and without visible details of the external sculpture. The internal view of the shell is lacking. The type material was never revised and the lack of information on this species caused many doubts to various mussel specialists: Ihering (1893) considered it to be a synonym of *D. psammactinus* (Philippi, 1848); Simpson (1914), Parodiz (1968, 1973), Mansur (1970), Simone (2006) and Graf & Cummings (2007) considered it to be a valid species, while Haas (1930, 1969a), Bonetto (1954), Zanardini (1965) and Rumi et al. (2008) categorized it as a subspecies of *Diplodon delodontus* (Lamarck, 1819).

Type locality

The type locality is at Cônego River, tributary of Grande River, municipality of Nova Friburgo, state of Rio de Janeiro, Brazil. Today, this river is completely modified by urbanization (Miyahira et al. 2012). It is part of the Grande River microbasin, tributary of the Paraíba do Sul River, with its headwaters originating in the state of São Paulo. It runs in a south to north direction until reaching the Atlantic Ocean in the north of state of Rio de Janeiro.

Type material of *Diplodon expansus*

The collection of Charpentier is preserved in the original cabinet as well as the respective register book. A very small green label with the catalogued number is glued to the external face of each shell (Fig. 5). There are nine specimens identified as *Unio expansus*, eight from Brazil and one from Mexico, all under the same number 160 (hereafter called MZL-CCh 160). In this collection, all specimens of the same species were registered together irrespective of sampling dates and origin of the material. Therefore each lot can be quite heterogeneous, as in the case of *D. expansus,* with one or more specimens from different sampling localities bearing the same collection number (Fig. 5). The specimen from Mexico is very similar to the other specimens of *D. expansus* but probably mislabeled. To substantiate this assumption it is important to consider that recent *Diplodon* species do not occur outside South America (e. g. Parodiz & Bonetto 1963); that there is a Grande River in Mexico as well; that the paper material and hand-writing on the labels from Mexico (Fig. 5D) differ from other locations (Fig. 5A,B,C) and were probably added later to lot MZL-CCh 160. Fortunately, most specimens have an individual label with original collection data. All Brazilian specimens were collected from the municipality of Nova Friburgo, state of Rio de Janeiro, from different tributaries of the same river basin (Grande River) in close proximity: four specimens from Grande River, two from Santo Antonio River, one from Cônego

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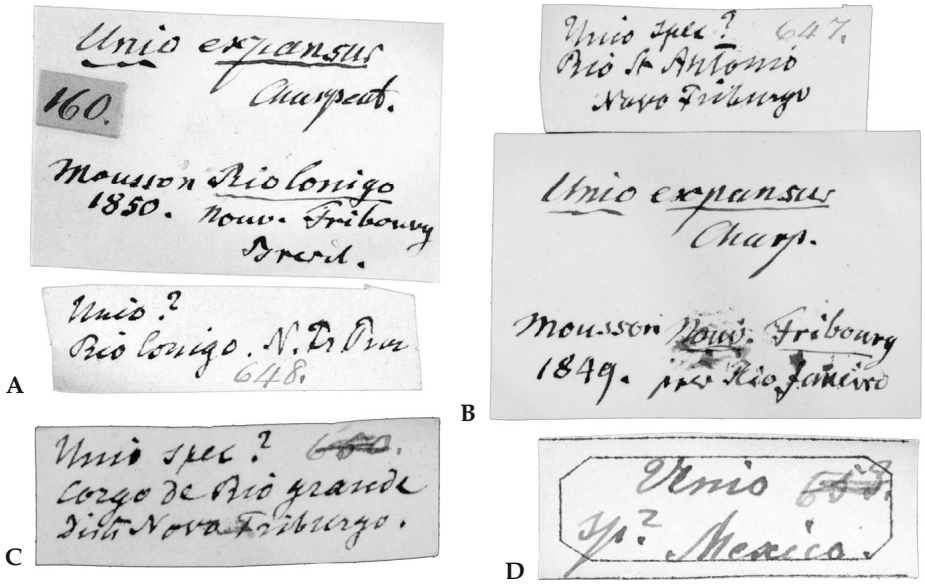

Fig. 5. Original labels of *Diplodon expansus* catalogued under the number 160 in the collection of Charpentier housed at Musée de Zoologie Lausanne. **A.** Label of the figured specimen of *Diplodon expansus* from Cônego River, Nova Friburgo, Brazil. **B.** Label from additional sample of *Diplodon expansus* from Santo Antonio River, Nova Friburgo. **C.** Label from *Diplodon expansus* from Grande River. **D.** Label from the specimen from Mexico. (Photos by Michel Kraft).

River and one specimen without specification of the river. There is no identification of the "type" status in any of these specimens.

Redescription of type specimen of *Diplodon expansus*

Original measurements by Küster (1856) are given in lines as 22 × 13 × 7 (length × height × width). Converting his measurements (1 line = 1/12 inch) results in 47 mm × 28 mm × 15 mm, respectively. Measuring Küster's drawings results in 47 mm × 29 mm × 18 mm. Our measurements of the specimen from Cônego River are 52.00 mm (length) × 31.99 mm maximum height × 17.59 mm width. The difference in length may be due to different ways of measuring, since height and width are much more similar.

Shell outline ovoid, following the table of Mansur & Pereira (2006). Anterior region lower than posterior, posterior-dorsal and ventral margins almost parallel, anterior end of shell rounded, posterior end obliquely truncated, posterior ridge double, slightly marked. Maximum height is 62.6 % of length, height at umbonal region 28.38 mm, 50.8 % of length. Umbones not elevated, located before first third of shell, at 28.8 % of total length. Shell not inflated; height almost three times greater than width (width = 34 % of length). Periostracum brown, slightly lustrous, concentric folds clearly marked, approximately 15 lines per cm in the area near the umbones, more spaced near ventral margin of shell. No remains of umbonal sculpture in this specimen, except for three small grains on antero-dorsal region of right valve. Hypostracum milky white and glossy. Right valve, two cardinal teeth of the same length, lower part slightly thicker, with a posterior projection resembling an accessory tooth, cardinal teeth finely crenulated; lateral tooth single. Left valve, single cardinal tooth and two lateral teeth, some transversal projections posterior of cardinal tooth, upper lateral tooth begins at umbo, lower lateral tooth begins posteriorly. Both lateral teeth slightly arched ending at impression of the posterior adductor muscle. Internal slope of lateral teeth finely crenulated, external slope smooth. Anterior muscle scars clearly delimited, posterior muscle scars marked. Shallow umbonal cavity.

On smaller specimens of MZL-CCh 160 one can see details of a conspicuous but fine umbonal sculpture (Fig. 6E–H) consisting of granular bars that cross each other, forming a zigzag pattern. There are also small flutings extending from the umbones to the middle of the shell over the ridge and dorsal slope.

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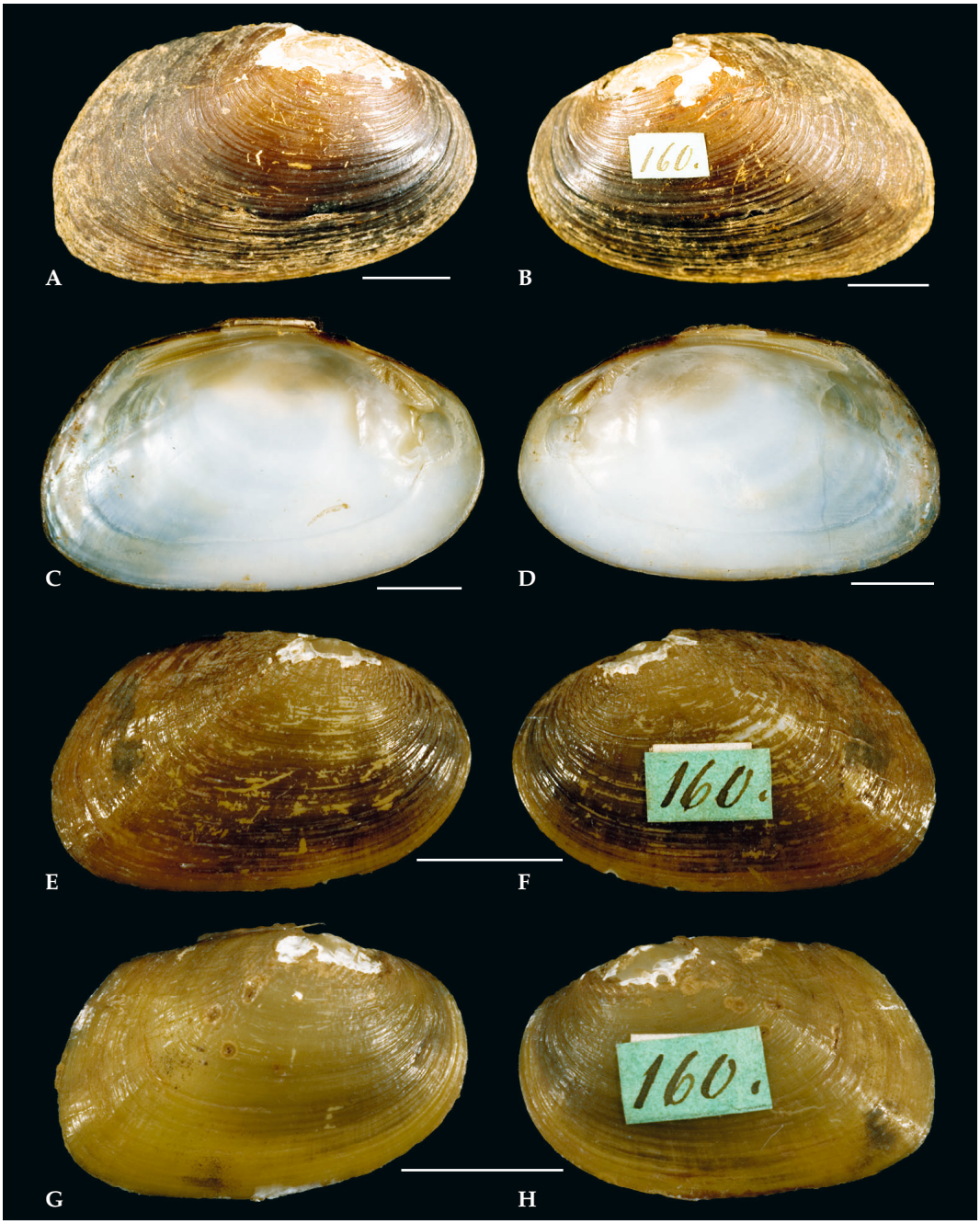

Fig. 6. Some specimens of the syntype series of *Diplodon expansus* Küster (1856) housed at Musée de Zoologie Lausanne. **A-D.** Specimen figured by Küster (1856), elected as lectotype. **E-H.** Smallest specimens of the series with details of external shell sculpture, elected as paralectotype. **A.** External view, right valve. **B.** External view, left valve. The same valve figured by Küster (1856). **C.** Internal view, left valve. **D.** Internal view, right valve. **E.** External view, right valve. **F.** External view, left valve. **G**. External view, right valve. **H.** External view, left valve. Scale bar = 1 cm. (Photos by Michel Kraft).

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Taxonomical conclusions and remarks

Küster (1856) does not mention the quantity of specimens he used to describe the species and presents illustrations of only one specimen, also figured here (Fig. 6A–D). Sample MZL-CCh 160 is composed of nine specimens from different localities, but from the same catchment, except for the questionable specimen from Mexico. Article 73.2.3 allows syntype series with specimens from different but proximate localities, as in the case of *D. expansus*. We therefore consider the MZL-CCh 160 as a syntype series of *D. expansus* from the Grande River microbasin in Rio de Janeiro, Brazil. As previously stated we consider the label from Mexico to be a mistake. Following the recommendation 74B of the ICZN (1999), we select the specimen (Fig. 6A–D) illustrated in the original description by Küster (1856: plate 43, fig. 5) as lectotype and the eight remaining specimens as paralectotypes.

Some authors (Bonetto 1954, Haas 1969a, Rumi et al. 2008) considered *Diplodon expansus* to be a subspecies of *Diplodon delodontus*. This relationship between *D. expansus* and *D. delodontus* may also be implied in recent works, e.g. Simone (2006). He considered the same distribution for *D. delodontus* and *D. expansus*, and excludes the state of Rio de Janeiro from the distribution of the latter, despite the fact that the type locality is in this state. The description of umbonal sculpture of *Diplodon expansus* presented here points to clear differences between *D. expansus* and *D. delodontus*. The umbonal sculpture of *D. delodontus* is composed of radial bars without grains. The sculpture described here for *D. expansus* is more similar to *Diplodon multistriatus* (Lea, 1831), and possibly indicates a close relationship between these two species.

Pereira et al. (2012) indicates the presence of *Diplodon expansus* in the watersheds of Paraná/Paraguay Rivers, the East Atlantic coastal rivers of Brazil, but raise doubts about its occurrence in the South/Southeast coastal rivers of Brazil. This redescription will help to elucidate the distribution of this species in Brazil.

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