

## Phenotypic diversity, taxonomic remarks and updated distribution of the Mediterranean *Jujubinus baudoni* (Monterosato, 1891) (Gastropoda Trochidae)

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### ABSTRACT

*Jujubinus baudoni* (Monterosato, 1891) shows highly diverse chromatic and morphological patterns. Based on the examination of the type material and series of specimens from private collections, and of recent findings from Sardinia, we reviewed and updated the distribution of this species, and figured the three representative shell colour morphs which are constant in local populations. A comparative SEM analysis did not outline significant differences among shells with greatly different colour patterns, thus justifying their belonging to a single specific entity. The survey of the material of *J. baudoni* did not show a strict correspondence between Corse and Sardinian shell colour morphs and their geographical distribution, not allowing to clearly state trends and relationships among island populations. On the contrary the colour pattern of the continental shells of *J. baudoni* seems to be constant and different from the ones of the island shells, indicating a well separated colour morph. This study confirmed that the distribution of *J. baudoni* is limited to the north-western Mediterranean Sea, with its eastern range widened to the La Maddalena Archipelago (Sardinia). The record of this species from Azores is due to a misidentification with *J. pseudogravinae* Nordsieck, 1973, which is also figured for comparison. A lectotype and paralectotypes of *Trochus baudoni* are herein designated.

### KEY WORDS

Trochidae; *Jujubinus baudoni*; Monterosato collection; colour morph; Mediterranean Sea.

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### INTRODUCTION

The genus *Jujubinus* Monterosato, 1884 was nominally based on *Trochus matoni* Montagu, 1803 and it is represented by a small group of marine gastropods living mostly in the intertidal zone down to about 80 m, invariably associated with photophilic algal vegetation and/or marine phanerogames. The alpha-taxonomy of this genus still has to be completely solved, but it is currently accepted that sev-

eral different species occur worldwide albeit, mainly on European waters, the exact number at the moment amounts to 29 according to WoRMS (World Register of Marine Species available at <http://www.marinespecies.org/index.php>; Appeltans et al., 2012). In particular, 18 taxa are listed by CLEMAM (at <http://www.somali.asso.fr/clemam/index.php>; Gofas & Le Renard, 2013) as European species, most of them restricted to the Mediterranean basin. Among the Mediterranean taxa be-

longing to this genus, *Jujubinus baudoni* (Monterosato, 1891) was reevaluated as bona species by Curini Galletti (1982). *J. baudoni* was described under the genus *Trochus* Linnaeus, 1758 by Monterosato (1891) with a very scanty description: “Il T. Baudoni, H. Martin mss., è una piccola forma grossesculpta, vivente in abbondanza sulle coste di Provenza” (“The T. Baudoni, H. Martin mss., is a small form heavily sculptured, abundant and living along the coast of Provence”). Since the paper of Curini Galletti (1982), only two further reports were recently published dealing with this species: by Scaperrotta et al. (2011), who figured shells from Corse, and by Spanu (2011) who reported specimens from the northwestern Sardinian coast. *J. baudoni* is present on the infralittoral zone and is considered locally common of the Catalan coast, Gulf of Lion, Corse and North-Western Sardinia (Curini Galletti, 1982; Scaperrotta et al., 2011; Spanu, 2011). The Azores Islands cannot be considered in the *J. baudoni* distribution, since the material examined in the Monterosato collection and labelled as *Calliostoma baudoni* coming from these islands, tentatively identified as *J. pseudogravinae* Nordsieck, 1973 by Curini Galletti (1982), has been confirmed to belong to this latter taxon. We have analyzed the type material of *Trochus baudoni* Monterosato, 1891 and *J. baudoni* var. *incomparabilis* Locard et Caziot (1901) (reported by CLEMAM as *J. baudoni incomparabilis* Ghisotti et Melone, 1975), and series of specimens of *J. baudoni* from private collections. A lectotype of *J. baudoni* is herein designated. We found that this species shows a great morphological variability, mainly concerning its colour pattern, which is very constant within the different population examined. A survey of colour morphs from different localities is here presented and, as far as to our knowledge, this study confirmed that the distribution of *J. baudoni* is limited to a restricted area of the North-Western Mediterranean basin, being slightly enlarged to east with the sampling of shells from the La Maddalena Archipelago (Sardinia). Shells from Monterosato's collection labelled as *J. baudoni* and *J. pseudogravinae* from the Azores are figured for comparison.

**ACRONYMS AND ABBREVIATIONS.** Carlo Smriglio and Paolo Mariottini collections, Rome, Italy (CS-PM); Monterosato (MTS); Museo Civico di Zoologia, Rome, Italy (MCZR); Scanning Electron Microscopy (SEM).

## MATERIALS AND METHODS

**EXAMINED MATERIAL.** We could examine the type material of *Trochus baudoni* in the Monterosato collection at the MCZR, consisting of empty shells: 134 exx from Paulilles (France); 30 exx from Roussillon (France); 12 exx from Département de l'Aude, Pyrénées Orientales (France); 20 exx *J. baudoni* var. *incomparabilis* from Pietranera, (Corse). A lectotype from the Paulille lot has been designated with the number MCZR00218 and the remaining material have been designed as paralectotypes MCZR00219/1-195. Furthermore, 18 exx from Azores (Portugal) MCZR 11761, named as *Calliostoma baudoni* but not related to this species, have been examined.

Other empty shells of *J. baudoni* examined: 2 exx from Cadaques (Spain), collected at a depth of 4 m; 3 exx from Capo Caccia, Sardinia (Italy), depth of 25 m. From La Maddalena Archipelago, Sardinia (Italy) further empty material was gathered among the shell grit collected handily by SCUBA diving: 59 exx from Caprera Is., depth of 25 m; 91 exx from La Maddalena Is., depth of 25 m; 62 exx of Spargi Is., depth of 20 m. Material referring to *J. pseudogravinae*: 8 exx from Azores (Portugal), dealer source. SEM photographs were carried out at the Interdepartmental Laboratory of Electron Microscopy (LIME), Università Roma Tre, Rome, Italy.

## RESULTS AND DISCUSSION

We analysed the type material of *T. baudoni*, including the *J. baudoni* var. *incomparabilis* shells, stored at the MCZR and we figured some shells and original labels (Figs. 1a-12b). The shells of *J. baudoni* var. *incomparabilis* well fit the description given by Locard and Caziot (1901): “Nous revelon une très belle var. incomparabilis (Mtr.), d'une coloration verte et rouge”. A lectotype and paralectotypes of *T. baudoni* have been herein designated. From the examination of these shells, and the accompanying labels, as well as of shells from private collections, we could confirm the systematic status of this species and derived its distribution. In fact, Monterosato's material labelled as *T. baudoni* from Azores (Figs. 13-15d) resulted to be *J. pseudogravinae* Nordsieck, 1973 after a literature research (Ávila et al., 2004; Ávila et al., 2007;

Ávila et al., 2011) and a direct comparison with shells of this endemic species (Figs. 16a-d, 29a-n). Most probably the bad conservation of the shells (sent by Dautzenberg, see handwriting label of Fig. 14) has induced Monterosato to identify wrongly these specimens, as already suggested by Curini Galletti who examined this material (1982). As far as we know, there are no reliable records of *J. baudoni* from Alboran Sea or Atlantic Ocean, including Azores islands. On the contrary, from literature and personal sampling (Figs. 17a-24b) the distribution of this species seems to be rather confined to the north-western Mediterranean basin (Ghisotti & Melone, 1975; Curini Galletti, 1982; Scaperrotta et al., 2011; Spanu, 2011).

The distribution of *J. baudoni* has been slightly enlarged to east with the shells collected by SCUBA diving in the La Maddalena Archipelago (Sardinia); in particular material was collected in the infralittoral zone from three islands of the Archipelago (Caprera, La Maddalena, Spargi) (Figs. 22a-24b; Table 1).

Regarding the morphological variability of this taxon, interestingly we found different phenotypes, being the shells (colour morph A) from the continental coast stouter, slightly more coarsely sculptured, showing prosocline reddish-brown and milky-white flammules, higher in number on the basal cordlet (Figs. 1a-8c; 17a-18c), in respect to the specimens from Corse and Sardinia. In turn, these latter can be divided in two different colour patterns regarding the teleoconch coloration: 1) the typical *J. baudoni* var. *incomparabilis* coloration (colour morph B), which consists in an emerald green background interrupted by bright orange and/or red flammules and milky-white prosocline stripes, with white spots on the basal cordlet (Figs. 9a, 12b, 19a-20b); 2) colour morph C, almost entirely brownish-green or with prosocline faint whitish flammules (Figs. 22a, 24b).

We recall that all *J. baudoni* shells invariantly show protoconch and initial teleoconch whorls of red colour. It is worth to mention that this feature has induced several authors in the past to erroneously identify *J. baudoni* as *J. exasperatus corallinus* (Monterosato, 1884) (Figs. 21a-c-30a-e), as recalled by Curini Galletti (1982) and Spanu (2011). Since it is possible to easily separate the three colour patterns, as well as the continental shells from the Corse and Sardinian ones, due to their slight dif-

ferences in the teleoconch sculpture, a comparative SEM analysis was carried out. The examination of the SEM photographs did not reveal any significant protoconch and teleoconch sculpture differences among all the shells analysed (Figs. 25a-28g), in spite of their diverse colour patterns, thus indicating that we are probably facing a single specific entity. It is a matter of fact, the colour pattern of the continental shells of *J. baudoni* seems to be constant and different from the ones of the island shells, indicating a well separated phenotype. On the contrary, shells of *J. baudoni* from Corse and Sardinia did not show a strict correspondence between colour morphs and their geographical distribution, not allowing to clearly state trends and relationships among island populations. In many marine gastropods a direct genetic control of shell coloration has been demonstrated, and in several cases variation in shell colour has been considered to be an adaptive value related to environmental variables such as climate, diet, habitat choice, insolation, salinity, visual predation and wave exposure (Terreni, 1981; Byers, 1989; Sokolova & Berger, 2000 and references therein; Miura et al., 2007). Shell colour may have three functions: communication, crypsis and thermoregulation, and it has been suggested that correlation between individual physiology and shell colour polymorphism is a result of pleiotropic effects of genes responsible for the shell colour or a linkage between them and genes determining certain physiological features (Sokolova & Berger, 2000 and references therein; Miura et al., 2007). The factors that maintain the color polymorphism, and those that contribute to among-site variation in color frequencies, remain unknown. Although the color polymorphism may have an underlying genetic component, the regional-scale variation in color frequency observed in *J. baudoni* could be ecologically controlled.

Interestingly, another member of the genus *Jujubinus*, *J. geographicus* Poppe, Tagaro et Dekker, 2006 shows a parallel shell colour variability (Figs. 31a, 32), including one very similar to the morph B (red-green pattern, Figs. 31a-c) and one entirely red (Fig. 32). In particular, green is a rare colour occurring in marine shell coloration and the occurrence of this colour in two different species so distantly geographically separated (Mediterranean and Philippines) could be due to a common genetic background the phenotype of which is selected by similar ecological constrains.





Figure 1. *Trochus baudoni*. MTS collection, lectotype MCZR00218, H = 6.5 x D = 5.2 mm, Paulilles (France). Figures 2-4. MTS collection, original labels. Figure 5. *T. baudoni*. MTS collection, 6.3 x 5.0 mm, Roussillons (France). Figures 6, 7. MTS collection, original labels. Figure 8. *T. baudoni*. MTS collection, 5.7 x 4.7 mm, Department de l'Aude (France).



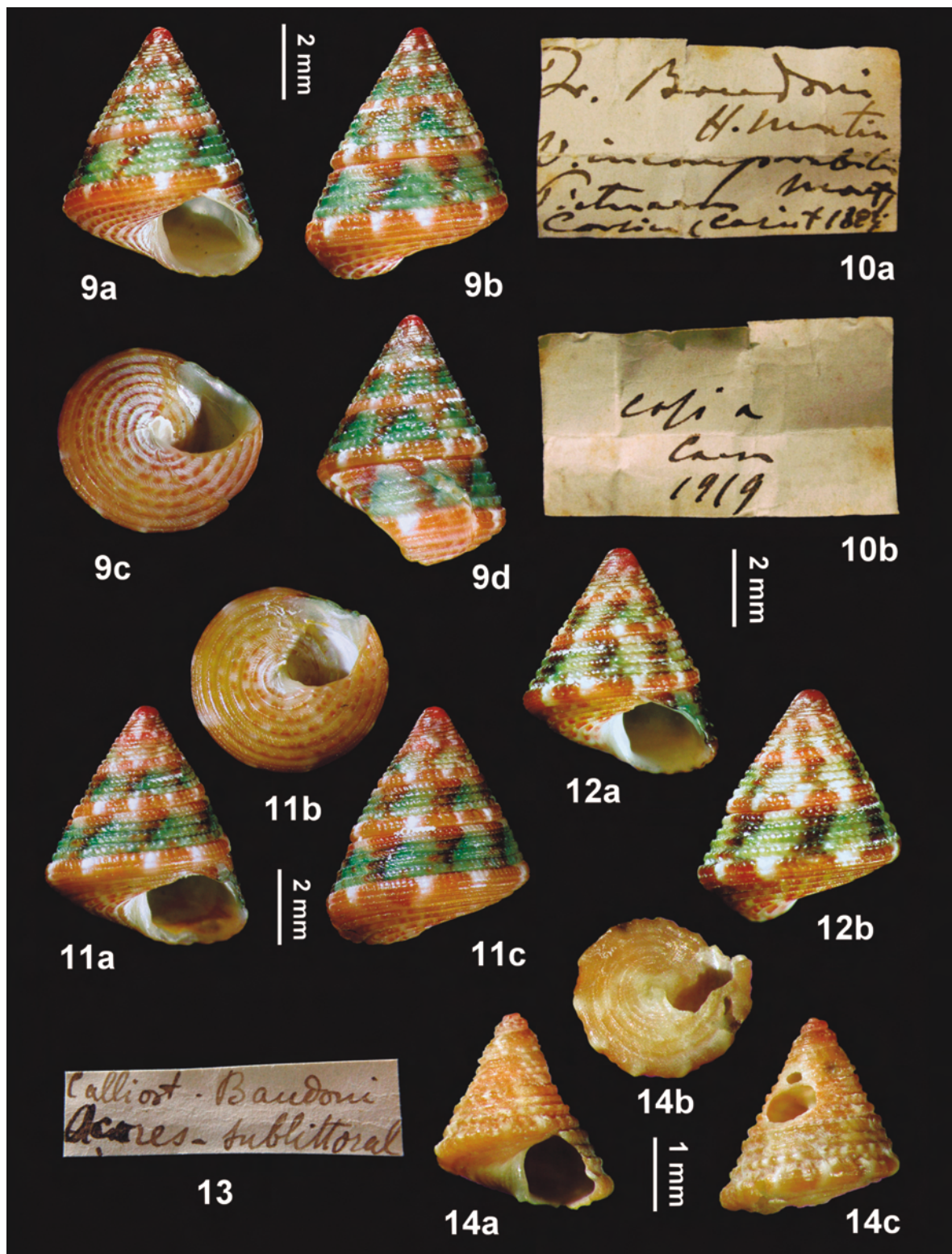


Figure 9. *Jujubinus baudoni* var. *incomparabilis*. MTS collection, H = 6.0 x D = 4.9 mm, Pietranera (Corse). Figure 10. MTS collection, original label. Figure 11. *J. baudoni* var. *incomparabilis*. MTS collection, 6.1 x 5.0 mm, Pietranera (Corse). Figure 12. *J. baudoni* var. *incomparabilis*. MTS collection, 5.4 x 4.8 mm, Pietranera (Corse). Figure 13. MTS collection, original label. Figure 14. *J. pseudogravinae*. MTS collection, 2.8 x 2.6 mm, Azores Islands.

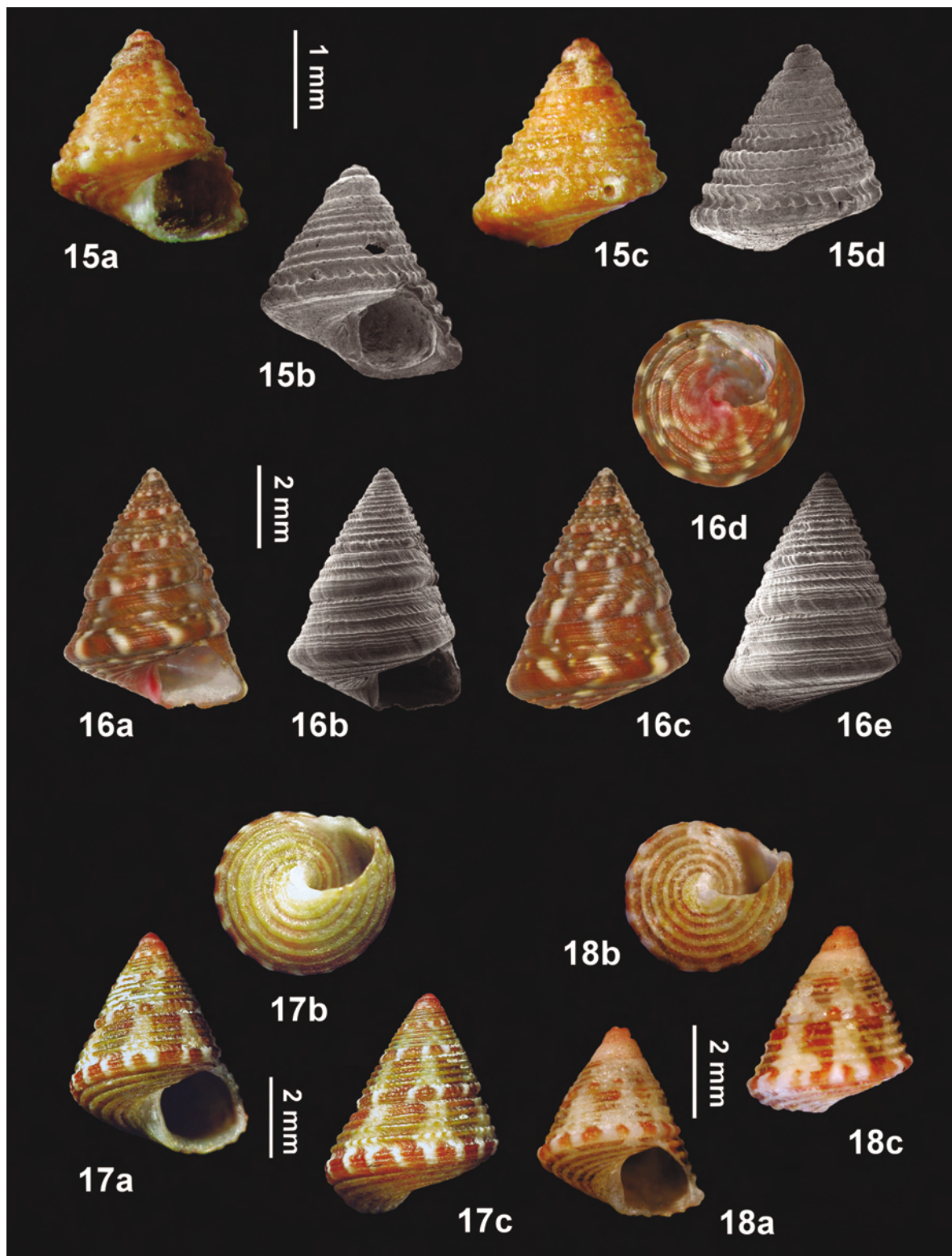


Figure 15. *Jujubinus pseudogravinae*. MTS collection, H = 2.7 x D = 2.6 mm, Azores Islands, MTS collection. Figure 16. *J. pseudogravinae*. CS-PM collection, 6.9 x 4.8 mm, Cais da Ribeirinha, S. Miguel Is. (Azores Islands), on stones, 10 m depth. Figure 17. *Jujubinus baudoni*. CS-PM collection, 5.5 x 4.4 mm, Cadaques (Spain), 4 m depth. Figure 18. *J. Baudoni*. CS-PM collection, 3.9 x 3.1 mm, Cadaques (Spain), 5 m depth.



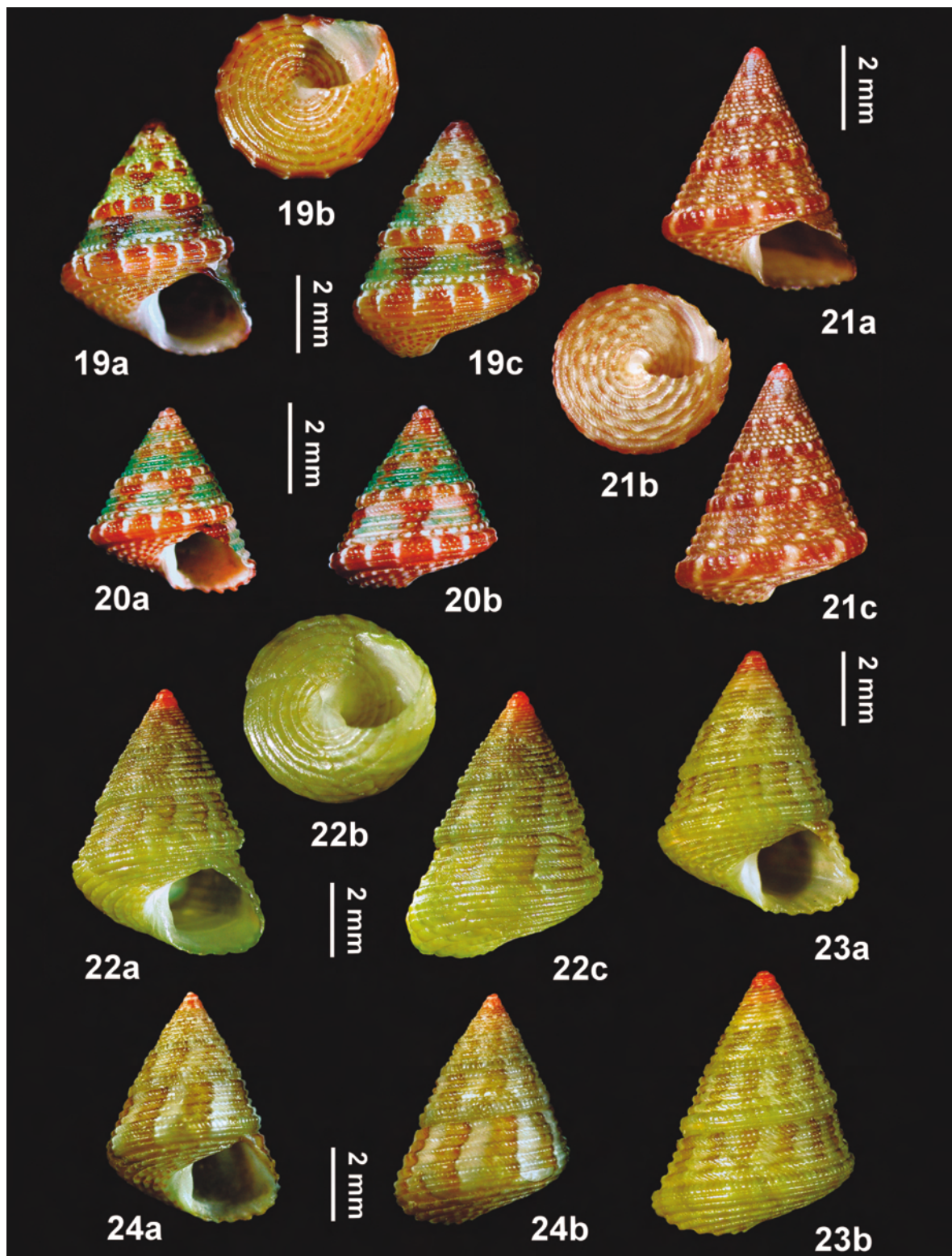


Figure 19. *Jujubinus baudoni* var. *incomparabilis*. CS-PM collection, H = 5.9 mm x D = 4.6 mm, Capo Caccia (Sardinia), 15 m depth. Figure 20. *idem*, 4.1 mm x 3.7 mm. Figure 21. *J. exasperatus corallinus*. CS-PM collection, 6.2 x 4.9 mm, La Maddalena Is. (Sardinia), 25 m depth. Figure 22. *J. baudoni*. CS-PM collection, 7.1 x 4.8 mm, La Maddalena Is., Sardinia, 25 m depth. Figure 23. *idem*, 7.1 x 4.9 mm, Caprera Is. (Sardinia), 30 m depth. Figure 24. *idem*, 6.0 x 4.2 mm.



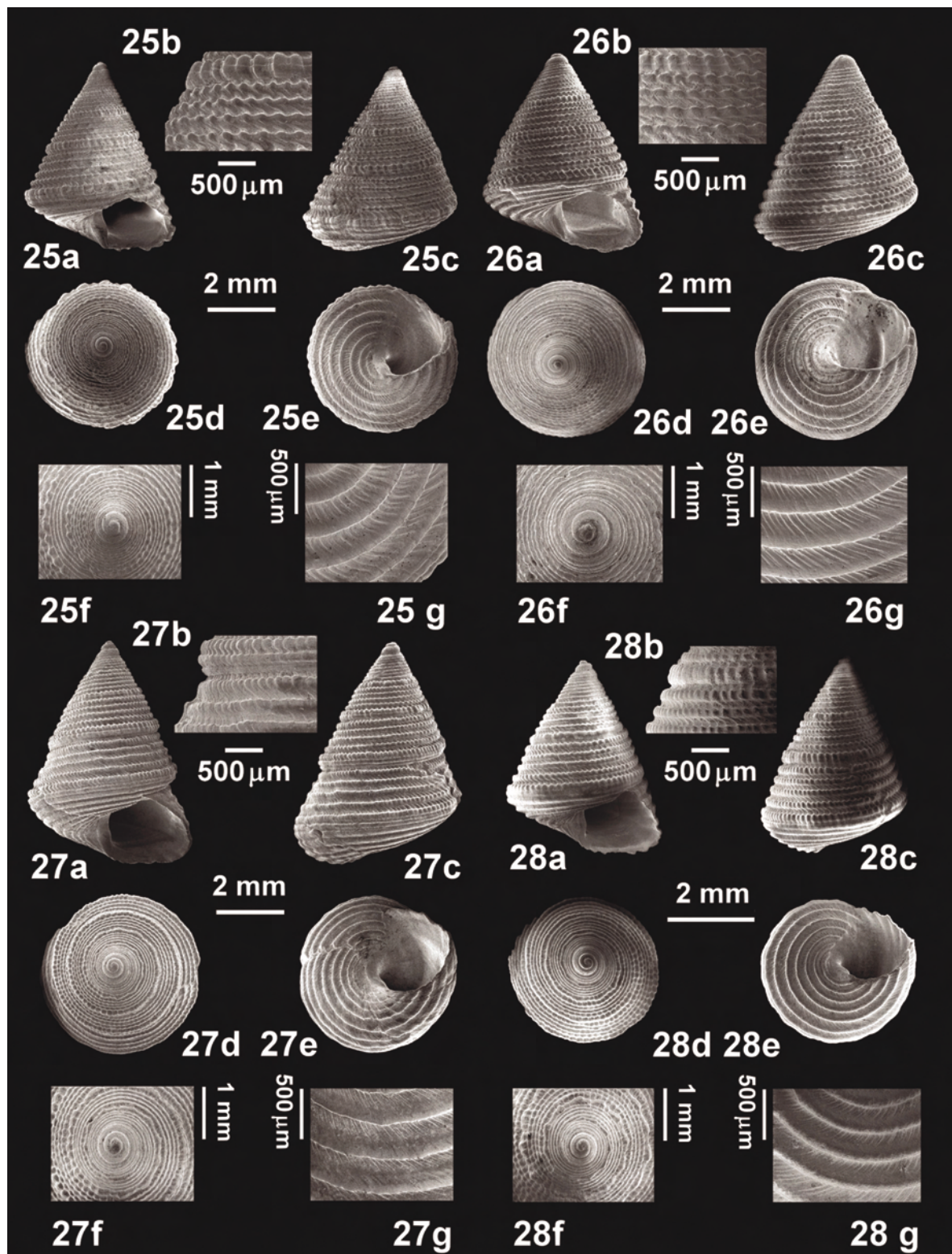


Figure 25. *Trochus baudoni*. MTS collection, H = 4.7 x D = 4.2 mm, Paulilles (France). Figure 26. *Jujubinus baudoni* var. *incomparabilis*. MTS collection, 6.1 x 4.8 mm, Pietranera (Corse). Figure 27. *J. baudoni* (Monterosato, 1891); specimen of figure 22. Figure 28. *J. baudoni*. CS-PM collection, 4.6 x 3.4 mm, Caprera Is. (Sardinia), 30 m depth.



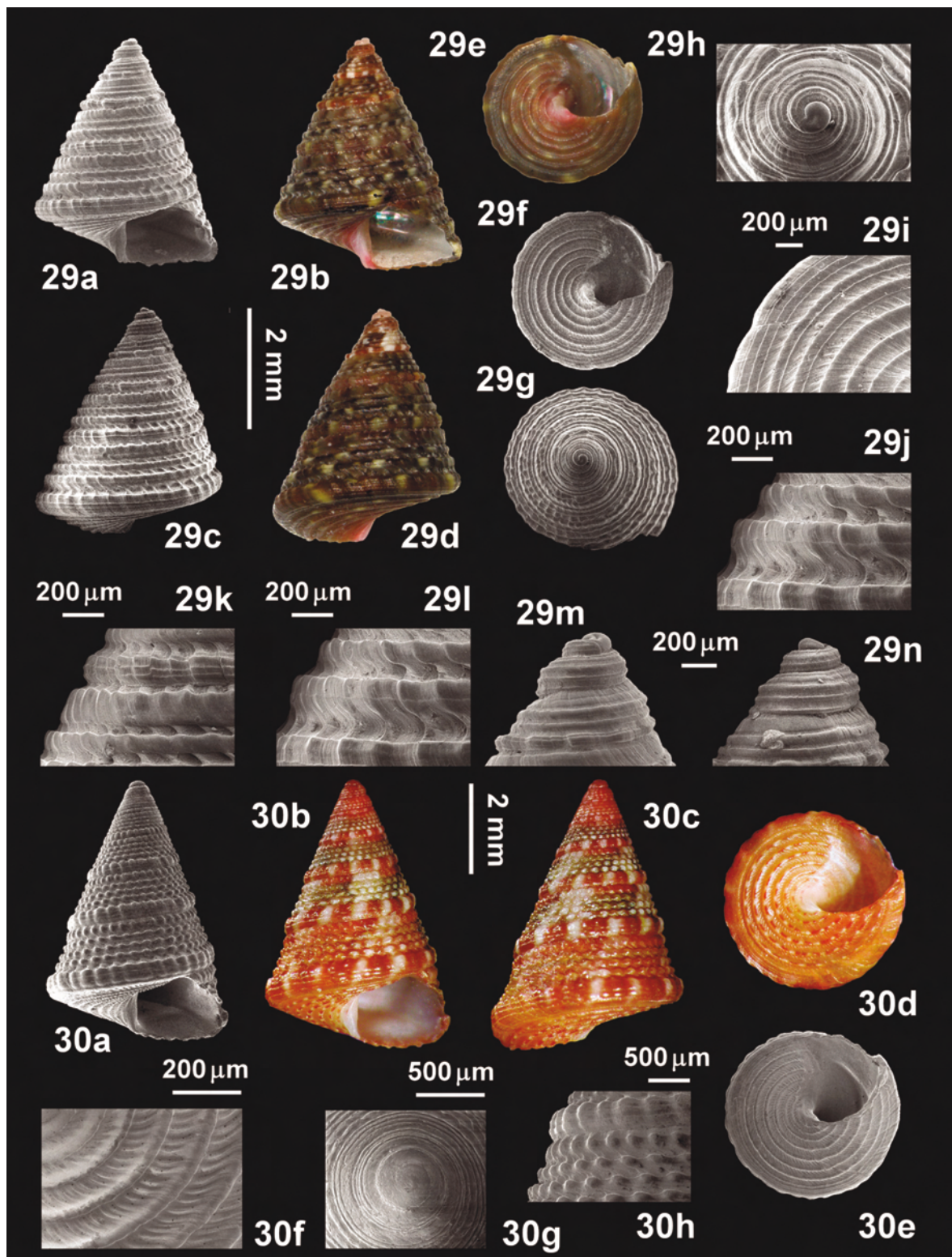


Figure 29. *Jujubinus pseudogravinae* Nordsieck, 1973. CS-PM collection, H = 4.5 x D = 3.0 mm, Cais da Ribeirinha, S. Miguel Is. (Azores Islands), on stones, 10 m depth. Figure 30. *J. exasperatus corallinus*. CS-PM collection, 6.8 x 4.6 mm, Bosa Marina (Sardinia), 30 m depth.

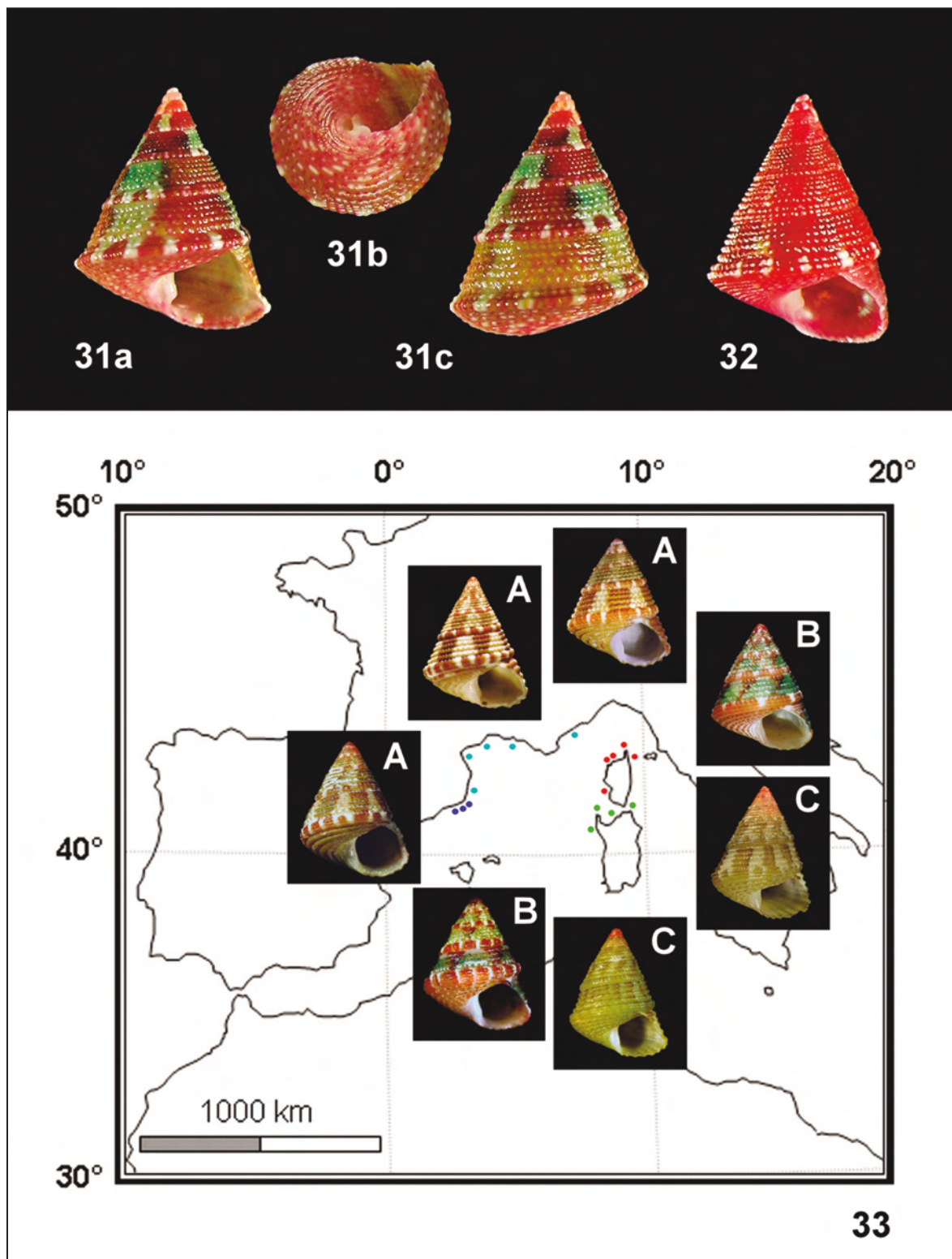


Figure 31. *Jujubinus geographicus*. Holotype, H = 4.9 x D = 3.9 mm, Punta Engano, Mactan Island (Philippines), 80-150 m depth. Figure 32. *J. geographicus*. Topotype, 4.8 x 3.3 mm, Punta Engano, Mactan Island (Philippines), 80-150 m depth. Fig. 33. *J. baudoni*. Morphotypes A-C distribution.



COAST	LOCALITY	REFERENCES
SPAIN	La Escala, Girona, Palamòs	Curini Galletti, 1982; Giannuzzi-Savelli et al., 1994
	Port Lligat, Cadaques	Spanu, 2011; this work
FRANCE	Paulilles, Roussillon; Dupott de l'Aude, Pyrénées Orientales	Monterosato, 1891
	Lérin Islands, Provence	Spanu, 2011
CORSE	Pietranera	Monterosato, 1891
	Ajaccio; Ile-Rousse; Barcaggio; Bastia	Locard & Caziot, 1901
	Revellata	Scaperrotta et al., 2011
SARDINIA	Capo Caccia, Alghero (Sassari); Asinara Island, Punta Aguada (Sassari); Costa Paradiso, Trinità d'Agultu (Olbia-Tempio)	Spanu, 2011; this work
	La Maddalena Archipelago (Olbia-Tempio)	This work

Table 1. Records of *Jujubinus baudoni* from the North-Western Mediterranean area (from literature and this work).

## CONCLUSIONS

Type material of *Trochus baudoni* and *Jujubinus baudoni* var. *incomparabilis*, together with other shells of this species have been analysed and figured in the present work. A lectotype and paralectotypes of *T. baudoni* have been designated. *J. baudoni* resulted to be represented by highly diverse chromatic shells, and three distinct colour morphs (A-C) have been recognized and figured, but comparative SEM analyses demonstrated that there are no significant differences in the shell sculpture, suggesting that they belong to a single specific entity. Since members of genus *Jujubinus* graze on a variety of micro-algal food sources, such as diatoms and green algal epiphytes (Peduzzi, 1987), we can infer that the different colour patterns observed in *J. baudoni* are influenced by diverse environmental factors. This could explain the occurrence of the same colour pattern in disjointed populations of the same geographical area, like the case of the colour morph B of Pietranera (Corse) and Capo Caccia (Sardinia), which are separated by the colour morph C (Fig. 33 and Table 1). However, we cannot rule out a different scenario, where those phenotypes correspond to a mosaic of sibling species. In the present study, we prefer to be con-

servative in non-assigning a taxonomic status to these different chromatic patterns. Genetic analyses are required to verify our current interpretation and further studies are necessary to reveal mechanisms maintaining shell colour polymorphism among populations of *J. baudoni* and understand if there is a physiological selection as a driving force shaping the pheno-(geno-)typic structure of these populations along the continental and island coasts. As far as we know, the distribution of *J. baudoni* is limited to the North-Western Mediterranean Sea, with its eastern range widened to the La Maddalena Archipelago (Sardinia) (Fig. 33). On the contrary, this species does not occur in the Azores, having been misidentified with *J. pseudogravinae*.

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