

A review of occurrence, distribution and alien status of *Notodiaphana atlantica* Ortea, Moro and Espinosa, 2013 and *Liloa mongii* (Audouin, 1826) (Mollusca: Heterobranchia) in the Mediterranean Sea

by

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Abstract

Notodiaphana atlantica and *Liloa mongii* are two cephalaspidean species described respectively from the Atlantic Ocean and the Red Sea, and considered widespread in their native ranges. Both species have also been recently recorded from the Mediterranean Sea, prompting some authors to consider them alien. Notwithstanding clear morphological differences in their shells, the two species have often been confused or misidentified in the literature, or specimens have been described with incorrect locality data. We hereby review the occurrence, distribution and status of both species in the Mediterranean Sea based on published data and examination of new material. *Notodiaphana atlantica* is considered a cryptogenic species with a range spanning from the western to eastern part of the basin. The presence of *L. mongii* in the Mediterranean is questioned until specimens that can be reliably assigned to this taxon or to any congeneric species are found in the area. Alien species inventories play an important role in regional policy and management decisions, thus requiring a high degree of confidence in the validity of species identification and their non-indigenous status. The present paper adds further evidence of the excess of “bibliographically introduced” alien records and reiterates the need for periodic re-evaluation of published data.

Key words: biological invasions, alien and cryptogenic species, faunal diversity, cephalaspideans, misidentifications

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1. Introduction

The introduction of marine alien species (MAS) into the Mediterranean Sea is an extensive process (Zenetos et al. 2010; 2012; 2017). Mollusca play a key role in this phenomenon, accounting for more than 200 taxa censused so far (Zenetos et al. 2012; Sabelli & Taviani 2014). The largest number of MAS in the Mediterranean Sea is reported to come from the Red Sea via the Suez Canal (the so-called Lessepsian migration: Gofas & Zenetos 2003; Zenetos et al. 2017). Recently, however, an increasing number of tropical or subtropical Atlantic species have also entered the area. Their status as native or alien is still widely debated because the Mediterranean basin was almost entirely recolonized by the Atlantic fauna after the re-establishment of the Atlanto-Mediterranean connection, and this process is presumably still ongoing (Crocetta et al. 2013; Canning-Clode & Carlton 2017). The situation is further complicated by morphological plasticity and discovered cryptic diversity, which can cause taxonomic complications, while minute sizes of species may result in underestimation of distribution ranges, with recent natural dispersals potentially being interpreted as human-induced introductions, and vice versa, due to vectors that can easily act even at small scale such as shipping, rafting on plastic debris, aquaculture, and so forth.

Among species recorded in the Mediterranean basin and corresponding to previous findings, the heterobranch taxa require special mention due to the complexity of their taxonomy and mode of life. For example, identifications of *Alys macandrewii* E.A. Smith, 1872 and *Okenia longiductis* Pola, Paz-Sedano, Macali, Minchin, Marchini, Vitale, Licchelli & Crocetta, 2019 have been uncertain and problematic or they have been consistently misidentified in the recent past for similar species, resulting in an overestimation of the number of alien species in the Mediterranean Sea (Micali et al. 2016; Pola et al. 2019). Juvenile specimens of the native species *Aplysia punctata* (Cuvier, 1803) were misidentified for almost a century as *Aplysia parvula* Mörch, 1863 and often listed as a Mediterranean alien or cryptogenic species (Crocetta et al. 2015; Corsini-Foka et al. 2015; Zenetos et al. 2016; Golestani et al. 2019). Finally, *Aplysia dactylomela* Rang, 1828 and *Bursatella leachii* Blainville, 1817 were commonly suspected to be Lessepsian migrants, while molecular data suggested they were Atlantic newcomers (Alexander & Valdés 2013; Valdés et al. 2013; Bazzicalupo et al. 2018; 2020). However, while the taxonomic issues concerning the above-mentioned taxa are now considered clarified, other species still

require further work even to resolve their distribution, with *Notodiaphana atlantica* Ortea, Moro & Espinosa, 2013 and *Liloea mongii* (Audouin, 1826) being two of them in particular.

Notodiaphana atlantica has only recently been described from the Atlantic Ocean (Ortea et al. 2013), whereas *L. mongii* is a taxon originally described from the Red Sea (Audouin 1826) and frequently recorded throughout the Indo-Pacific area under the name *Bulla curta* A. Adams, 1850, a junior synonym (*vide* Micali 2014). The Mediterranean distribution of both taxa was recently discussed by Micali (2014), who considered *N. atlantica* as widespread in the western and central Mediterranean Sea (Morocco, France, Italy, Malta, and Tunisia), and *L. mongii* as recorded only in the Mediterranean Sea from Cyprus, based on specimens previously recorded by Cecalupo & Quadri (1996) and identified as *Cylichnina* cfr. *mongii*. Notwithstanding such a review, and as part of our work on alien and cryptogenic molluscan species in the Mediterranean Sea, we have noted some discrepancies with respect to the available literature.

We therefore proceed to review the Mediterranean records of these two heterobranch taxa by analyzing published and unpublished material with the objective to shed some light on the occurrence, distribution and alien status of both species in the basin.

2. Materials and methods

2.1. Published and unpublished data

Both indexed and grey literature was reviewed for published Mediterranean records of *Notodiaphana atlantica* and *Liloea mongii*. The material examined in the present paper was collected from the bioclastic bottom by scuba diving or dredging. Comparisons were made with material illustrated in recent studies and samples collected from several localities, all listed below. The analyzed material is currently preserved in private collections (explanation under individual records).

2.2. Identification, taxonomy, and laboratory work

Identifications follow the literature and/or type material referenced below. The updated taxonomy and nomenclature used in this study follow MolluscaBase (2020). Shells were examined using Kyowa SDZ-PL (Japan), Labolan S.L., Lomo MBC-10 (Russia), and Olympus SZ61 (Japan) stereomicroscopes, and measurements were carried out using an eyepiece micrometer. Selected shells and their details were



also examined using Philips XL30 (the Netherlands) and Quanta200 (Massachusetts) scanning electron microscopes (SEMs) in the Centro de Apoyo Científico y Tecnológico a la Investigación (CACTI) – University of Vigo, after air drying and mounting on SEM stubs.

2.3. Abbreviations and acronyms

The following abbreviations and acronyms were used:

- sh – empty shells;
- lv – live specimens;
- APC – Attilio Pagli collection (Lari, Italy);
- ARC – Alessandro Raveggi collection (Firenze, Italy);
- CBC – Cesare Bogi collection (Livorno, Italy);
- FAC – Franco Agamennone collection (Pescara, Italy);
- LTC – Lionello P. Tringali collection (Roma, Italy);
- SBC – Stefano Bartolini collection (Firenze, Italy).

3. Results

Systematics

- Class Gastropoda Cuvier, 1795
- Subclass Heterobranchia Burmeister, 1837
- Order Cephalaspidea P. Fischer, 1883
- Family Notodiaphanidae Thiele, 1931
- Genus *Notodiaphana* Thiele, 1917
- Notodiaphana atlantica* Ortea, Moro & Espinosa, 2013
(Figures 1A–C, 2, 3A)

Cylichnina multiquadrata (Oberling, 1970) – Cachia et al. (1993): 40 [Malta]; Sammut & Perrone (1998): 223 [Malta]; Cachia (1999): 105 [Malta]; Cachia et al. (2001): 125, 228–229, plate XX, Fig. 7 [Malta]; Cachia et al. (2004): 256 [Malta]; Cachia et al. (2019): 145 [Malta]

? *Cylichnina multiquadrata* (Oberling, 1970) – Buzzurro & Greppi (1997): 9 [Tasucu, Turkey] — see Cecalupo et al. (2008); Micali (2014)

? *Cylichna cf. mongii* (Audouin, 1826) – Zenetos et al. (2004): 323 [Djerba Island, Tunisia and Akkum, Turkey, *vide* van Aartsen]

Cylichna cf. mongii (Audouin, 1826) – Delongueville & Scaillet (2007): 56–58, Fig. 25 [Djerba, Tunisia; Side and Taşucu, Turkey]

Cylichnina multiquadrata (Oberling, 1970) – Cecalupo et al. (2008): 128–129, plate 75, Figs 4–8 [Djerba and Kerkennah Islands, Tunisia]

? *Cylichnina cfr. mongii* (Audouin, 1827) – Vazzana (2010): 71 [Scilla, Italy]; Vazzana (2011): 61 [Scilla, Italy] — see Micali (2014)

Cylichna cf. mongii sensu van Aartsen – Cossignani & Ardochini (2011): 371, figures [Malaga, Spain] — incorrectly reported from Spain, but found at

Kerkennah Islands, Tunisia: see Cecalupo et al. (2008): plate 75, Figs 4–6 as *Cylichnina multiquadrata* and Micali (2014)

Cylichnina multiquadrata (Oberling, 1970) – Perna (2013): 243, figure [Scilla, Italy]

Notodiaphana atlantica Ortea, Moro et Espinosa, 2013 – Micali (2014): 499–504, Figs 3–6, 12–16 [Djerba, Tunisia; Messina, Augusta, and Linosa, Italy; Tétouan, Morocco] – Figs 13 and 15–16 incorrectly reported from Tunisia, but found in Cyprus: see Scaperrotta et al. (2016)

Retusa sp. – Oliver et al. (2015): 111, 142, 144, Figs 179–182 [Chafarinas Islands, Spain]

Notodiaphana atlantica Ortea, Moro & Espinosa, 2013 – Scaperrotta et al. (2016): 25, 110, figures [Kerkennah Islands, Tunisia and Protaras, Cyprus]

Notodiaphana atlantica Ortea, Moro et Espinosa, 2013 – Giacobbe & Renda (2018): 29, 30, 31, Fig. 6 [Capo d'Armi, Italy]

Notodiaphana atlantica Ortea, Moro & Espinosa, 2013 – Albano et al. (2020): 4065, Figs k–l [Rosh Carmel plateau and off Atlit, Israel]

Material examined: Morocco – 3 sh, Cabo Negro, 30 m, 2006 (CBC and APC). Italy – 1 sh, Isola delle Correnti (Portopalo di Capo Passero), 1.5 m, 28.viii.1992 (LTC); 6 sh, Pellaro, 26 m, vii.2009 (SBC, APC, and CBC); 1 lv, Cannitello, 40 m, vii.2009 (SBC). Tunisia – 3 sh, Djerba, 1 m, viii.1989 (CBC) [partially published in Micali (2014), namely Figs 3–5]; 17 sh, *Sidi Youssef (Kerkennah)*, 0.5–1 m, vi.2009 (SBC) [partially published in Micali (2014), namely Figs 12 and 14 and Scaperrotta et al. (2016)]; Figures 1A–B. Greece – 2 sh, Malia, 4 m, 2015 (APC). Cyprus – 7 sh, Protaras, 26–30 m, vi.2011 (CBC and SBC) [partially published in Micali (2014), namely Figs 13, 15, and 16, incorrectly stated as coming from Djerba, Tunisia, and Scaperrotta et al. (2016)] (Figure 3A). Israel – 1 sh, Akko, 3 m, vi.1996 (LTC); 1 sh, Tel Aviv, 30 m, 14.x.2002 (CBC) (Figure 1C); 1 sh, Haifa, 18 m, unknown date (CBC).

Updated distribution: described from the Canary Islands (Ortea et al. 2013) [Lanzarote] and known from the western Atlantic {e.g. Redfern (2001): 154, plate 68 (Fig. 642A), plate 113 (Fig. 642B) as *Cylichnid* sp. A [Bahamas]; Valdés et al. (2006): 22–23 as *Retusa* sp. 1 [Venezuela]; Redfern (2013): 257 (Figs 722A–D) as *Retusa* sp. [Bahamas]; Ortea et al. (2013): 17, (Figs 4B, D) [Cuba]; Tunnell et al. (2010; 2014): 279 and 128, respectively, as *Haminoea succinea* (Conrad, 1846) [Texas, U.S.A.]; Zhang (2012): 171 (Fig. 671) as *Atys mandrewii* E.A. Smith, 1872 [Antigua and Barbuda]} and the eastern Atlantic {e.g. Mikkelsen (1995): 205 (Fig. 2E) as *Retusa multiquadrata* [Azores, Portugal]; Ávila et al.

(1998): 502 as *Retusa multiquadrata* [Azores, Portugal]; Segers et al. (2009): 41, 251, 498–499 (plate 55, Figs 2–2a) as *Retusa multiquadrata* [Madeira, Portugal]; Ortea et al. (2013): 17, (Figs. 4C, 4E, plate 1) [Canaries, Spain]; Ortea & Moro (2018): 40 (Figs 1B–C) [Cabo Verde]; Delongueville et al. (2019): 40 (Fig. 4B) [Azores, Portugal]] and from the western to eastern part of the Mediterranean Sea (references and unpublished material listed above).

Shell description: small (up to 5 mm, usually much smaller), thin, translucent, almost twice as long as wide, subcylindrical-pyriform in outline, involute, with maximum width below the last whorl periphery. Aperture longer than spire, with anterior end rounded and wider than posterior end. Outer lip sharp, straight to slightly concave. Umbilicus narrow, partially covered by projection of thickened columellar lip. Columellar lip unfolded. Spire concave, deeply sunken, nearly covered by the last whorl, leaving a narrow apical umbilicus. Shell surface covered with thin, close, irregular spiral furrows. Spiral sculpture crossed, sometimes interrupted by orthocline, somewhat sinuous, axial growth lines, giving the surface a faintly reticulated appearance. Axial sculpture stronger within apical depression. Color uniformly whitish.

Remarks: supraspecific and specific taxonomy of *N. atlantica* has been widely debated in the recent literature. In fact, its generic assignment has been recently questioned by Oskars et al. (2015), who suggested that the genus *Notodiaphana* Thiele, 1917 and the family Notodiaphanidae Thiele, 1931 should be considered as *nomina dubia*. However, we hereby used it cautiously according to MolluscaBase (2020). Moreover, Giacobbe & Renda (2018) suggested that *N. atlantica* may comprise a complex of species based on a putative disjunct distribution in the western Atlantic and the Mediterranean Sea. Based on the present results, however, *N. atlantica* shows a broad amphi-Atlantic distribution, ranging uninterruptedly from the western Atlantic Ocean to the eastern Mediterranean Sea, having also been widely recorded from Macaronesia (eastern Atlantic) as *Retusa multiquadrata* (see Updated distribution). Nonetheless, an integrative taxonomic approach could confirm or refute this statement. With regard to its distribution in the Mediterranean Sea, Micali (2014) originally reported *N. atlantica* from the western and central parts of the basin, although according to subsequent reports by Scaperrotta et al. (2016) and Albano et al. (2020), its distribution also includes the eastern Mediterranean. The species has been mostly reported

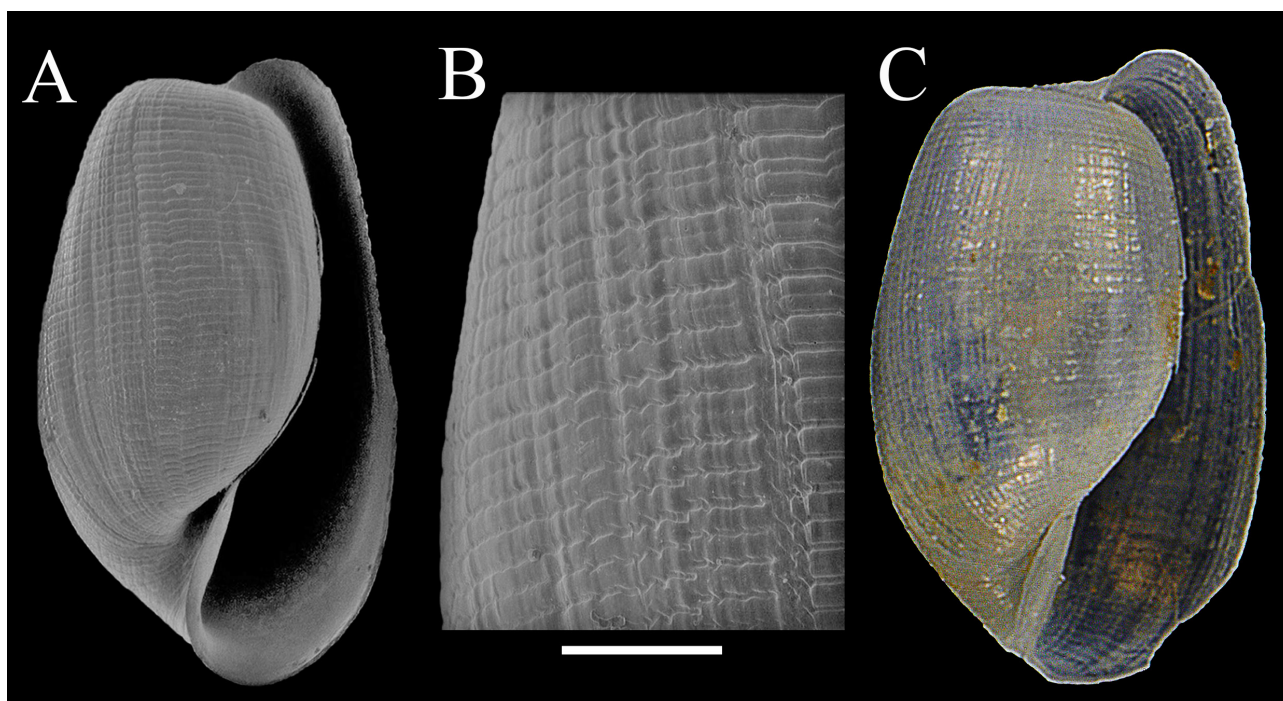


Figure 1

Notodiaphana atlantica from the Mediterranean Sea. Specimens not to scale. **A.** SEM photo of a specimen from Sidi Youssef, the Kerkennah Islands (Tunisia), height 3.3 mm. **B.** Details of the sculpture of the specimen in Fig. 1A (SEM photo). Scale bar: 300 μ m. **C.** Light photo of a specimen from Tel Aviv (Israel), height 2 mm (image by Stefano Bartolini)



from the basin as *Cylichnina multiquadrata* (Oberling, 1970), a taxon whose identity is still uncertain (Crocetta & Tringali 2015; Crocetta et al. 2015), and *Cylichnina/Cylichna* (cf) *mongii* (Audouin, 1826), which is discussed below. Although most of the records listed above illustrated the material examined, thus confirming what is reported here, three records (Buzzurro & Greppi 1997; Zenetos et al. 2004; Vazzana 2010) lack images and are listed here with a preceding question mark. However, as *N. atlantica* is widespread at the localities investigated there, the three questionable records presumably also referred to *N. atlantica*. The updated distribution of *N. atlantica* in the Mediterranean Sea is reported in Figure 2.

Family Haminoeidae Pilsbry, 1895
Genus *Liloe* Pilsbry, 1921
Liloe mongii (Audouin, 1826)

Not *Cylichnina* cfr. *mongii* (Audouin, 1827) – Cecalupo & Quadri (1996): 98–99 (plate 3, Figs 1–1a–1b) [Kyrenia, Cyprus] – figures first re-published online (Coppini 2002) and then in print (Coppini 2004); see Ortea et al. (2013)

Not *Cylichna* cf. *mongii* (Audouin, 1826) – Zenetos et

al. (2004): 323 [Island of Djerba, Tunisia and Akkum, Turkey, *vide* van Aartsen]

Not *Cylichnina* cfr. *mongii* – Repetto et al. (2005): 258 (Fig. 1136) [Eastern Mediterranean Sea]

Not *Cylichna* cf *mongii* (Audouin, 1826) – Delongueville & Scaillet (2007): 56–58, Fig. 25 [Djerba, Tunisia; Side and Taşucu, Turkey]

Not *Cylichnina* cfr. *mongii* (Audouin, 1827) – Vazzana (2010): 71 [Scilla, Italy]; Vazzana (2011): 61 [Scilla, Italy] – see Micali (2014)

Not *Cylichna* cf. *mongii* *sensu* van Aartsen – Cossignani & Ardovini (2011): 371, figures [Malaga, Spain] – incorrectly reported from Spain, but found at the Kerkennah Islands, Tunisia: see Cecalupo et al. (2008): plate 75, Figs 4–6 as *Cylichnina multiquadrata* and Micali (2014)

Not *Cylichnina mongii* (Audouin, 1827) – Perna (2013): 243, figure [Kos, Greece]

Shell description (based on the holotype): minute (1.5 mm) but not thin, opaque, almost twice as long as wide, ovate-cylindrical in outline, involuted, with maximum width around the middle of the last whorl periphery. Aperture longer than spire, with anterior end rounded and wider than posterior end. Outer lip

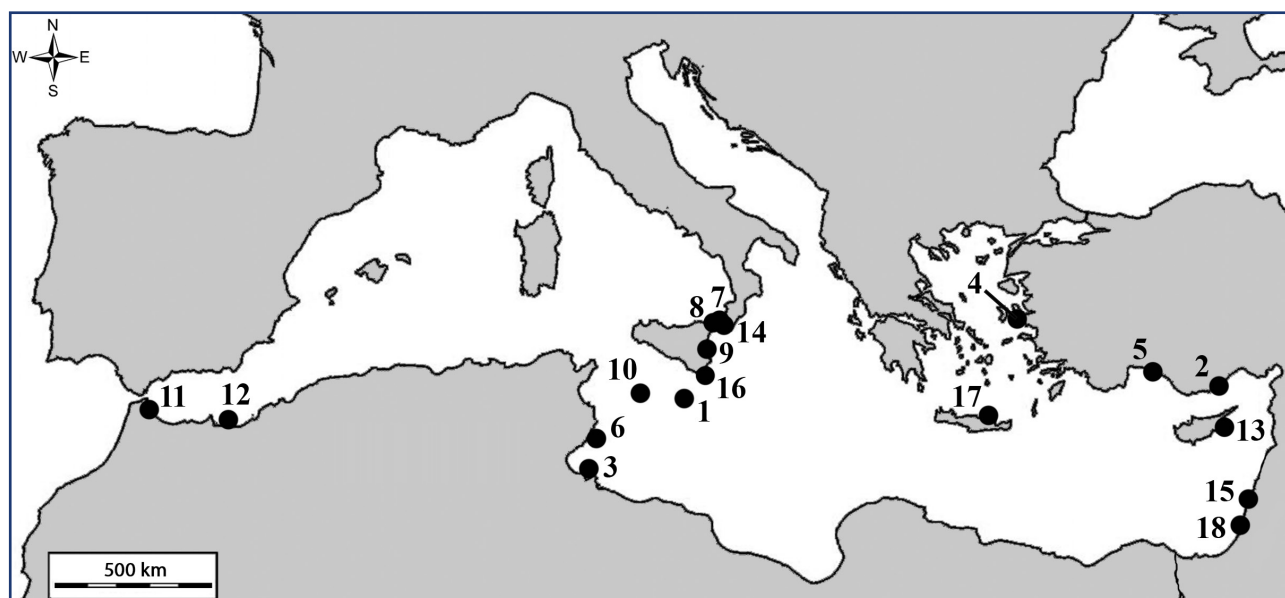


Figure 2

Updated distribution of *Notodiaphana atlantica* in the Mediterranean Sea. Data derived from the literature and this study; records arranged in chronological order. Localities (see listed records and material examined): 1 – Malta; 2 – Taşucu, Turkey; 3 – Island of Djerba, Tunisia; 4 – Akkum, Turkey; 5 – Side, Turkey; 6 – the Kerkennah Islands, Tunisia; 7 – Scilla and Cannitello, Italy; 8 – Messina, Italy; 9 – Augusta, Italy; 10 – Linosa, Italy; 11 – Tétouan and Cabo Negro, Morocco; 12 – Chafarinas Islands, Spain; 13 – Protaras, Cyprus; 14 – Capo d’Armi and Pellaro, Italy; 15 – Rosh Carmel plateau, Atlit, Haifa, and Akko, Israel; 16 – Isola delle Correnti, Italy; 17 – Malia, Greece; 18 – Tel Aviv, Israel

apparently broken, regularly curved. Umbilicus narrow, partially covered by projection of thickened columellar lip. Columellar lip unfolded. Spire concave, deeply sunken. Shell surface covered with thin, close, irregular spiral furrows. Spiral sculpture crossed by orthocline axial growth lines, giving the surface a reticulated appearance. Axial sculpture present within apical depression. Color whitish.

Remarks: *Liloa mongii* was originally described from an unknown locality in Egypt, very likely from the Egyptian Red Sea; see Amati et al. (2019) for discussion. The holotype of *L. mongii*, most likely a juvenile (~1.5 mm high), was described by Bouchet & Danrigal (1982: Fig. 58) and Valdés & Héros (1998: Fig. 4A), whereas Ortea et al. (2013: Fig. 6) erroneously assigned the holotypes of both *Bulla girardi* Audouin, 1826 (namely Fig. 6A) and *Bulla mongii* Audouin, 1826 (namely Fig. 6B) to the latter species. Based on the recent literature, *L. mongii* appears to have a wide distribution covering a large part of the Indo-Pacific region and the Red Sea, where it was mostly recorded under its junior synonym *Bulla curta* A. Adams, 1850 (e.g. Micali 2014; Too et al. 2014; Oskars et al. 2019). Moreover, Micali (2014) reported it also from the Bitter Lakes and the Mediterranean Sea, where it was considered a Lessepsian immigrant. However, the synonymy between *L. mongii* and *L. curta* is poorly supported, the variability and growth of “true” *L. mongii* was never properly investigated, and a review of the recent literature concerning the Indo-Pacific region showed that *L. curta* shows high variability in shell shape and sculpture and may comprise a complex of species. Finally, the congeneric *Liloa porcellana* (Gould, 1859) may fall within the range of variability of the two *Liloa* species mentioned above, or all these species may have been frequently mixed up in the recent literature (e.g. Higo et al. 2001; Poppe 2008; Rushmore-Villaume 2008; Severns 2011; Micali 2014; Chaban 2016; Okutani 2017). With regard to the records published from the Mediterranean Sea, the majority of them concern *N. atlantica* (see above). On the other hand, the record from Cyprus described by Cecalupo & Quadri (1996) and considered by Micali (2014) as the only confirmed record of *L. mongii* from the Mediterranean Sea, is based on three empty shells whose sizes cannot be fully determined. Two of them (Figs 1, 1a) show an irregular outline, with the largest one (Fig. 1) showing a spiral striate or even reticulate sculpture, whereas the sculpture is not well visible in the smallest specimen (Fig. 1a). The third shell (Fig. 1b) shows an outline resembling *N. atlantica*, but the figure is completely blurred. Noteworthy, the largest of these specimens was also presumably

redrawn in the malacological atlas by Repetto et al. (2005). Based on the photos published by Cecalupo & Quadri (1996), these three specimens do not correspond with certainty to *N. atlantica*, and not even to the holotype of *L. mongii* or *L. mongii sensu* Micali (2014). Unfortunately, the specimens figured by Cecalupo & Quadri (1996) cannot be re-examined due to the untimely death of the latter author in 1998 (A. Cecalupo, personal communication), so they remain here as unidentified. Finally, the record by Perna (2013) from Kos (Greece) is based on a shell with a total height of 1.5 mm, thus comparable to the holotype of *L. mongii*. However, it is completely different in shape and sculpture from *L. mongii*. A comparative table illustrating *N. atlantica*, the holotype of *L. mongii*, *L. mongii sensu* Perna (2013) and *L. mongii sensu* Micali (2014) is provided in Figure 3.

4. Discussion

Alien species inventories play a key role in providing information needed for regional policy and management decisions, as well as in identifying resource allocation priorities. For example, the Convention on Biological Diversity (2000) requires the “compilation and dissemination of information on alien species that threaten ecosystems, habitats, or species, to be used in the context of any prevention, introduction and mitigation activities”, or the European Union’s Marine Strategy Framework Directive (MSFD) lists the Descriptor D2 (addressing NIS – Non Indigenous Species) among the parameters to be addressed when establishing the Good Environmental Status (GES) of an area.

We have thus contributed to the above-mentioned scopes by reviewing the occurrence, distribution and alien status of *N. atlantica* and *L. mongii* in the Mediterranean basin. In fact, before our review, *N. atlantica* was considered an invasive alien species and *L. mongii* was considered a Lessepsian invader (Micali 2014; Forli 2016), whereas after our review, *N. atlantica* should be considered a cryptogenic species whose distribution extends from the western to eastern Mediterranean Sea, and the presence of *L. mongii* in the basin is questioned because a shelled heterobranch species (presumably ascribable to the genus *Liloa*) occurs in the Bitter Lakes, but its invasion in the Mediterranean Sea is not fully established.

With regard to the Mediterranean biota, several authors have already pointed out that the phylum Mollusca generally suffers from the inflation of “bibliographically introduced” alien records (e.g. Zenetos et al. 2004; Crocetta et al. 2017; 2020),



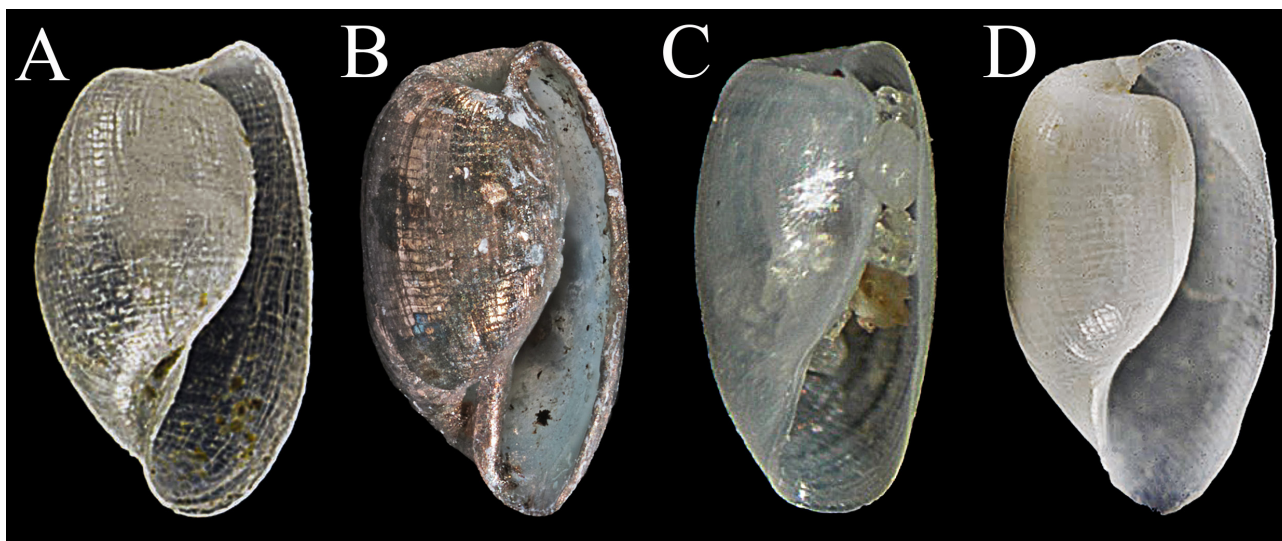


Figure 3

Comparative table of species/specimens discussed in the present study. Specimens not to scale. **A.** *Notodiaphana atlantica* from Protaras (Cyprus), height 1.7 mm (after Micali 2014; image by Stefano Bartolini). **B.** *Bulla mongii* holotype (MNHN-IM-2000-25856), Egyptian Red Sea, height 1.5 mm (image by Philippe Maestrati/MNHN using the Dun, Inc. BK PLUS Digital Imaging System). **C.** *Liloa mongii sensu* Perna (2013) from Kos Island (Greece), height 1.5 mm (after Perna 2013; image by Edoardo Perna). **D.** *Liloa mongii sensu* Micali (2014) from Bitter Lakes (Egypt), height 1.4 mm (after Micali 2014 & Scaperrotta et al. 2016; image by Stefano Bartolini)

which presumably can be attributed to local and international shell collectors and other groups of citizen scientists, such as tourists, who are eager for new findings and can publish their presumptive results in amateur or even indexed journals. All this strongly suggests that the scientific community is often urged to carefully assess the accuracy and veracity of published inventories (Ojaveer et al. 2014; Zenetos et al. 2017), and this paper adds further evidence to this.

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