

A new alien limpet for the Mediterranean: *Lottia* sp. (Patellogastropoda Lottiidae)

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ABSTRACT

Some living specimens of a new limpet were found between January and August 2015 in the intertidal of the eastern coast of Sicily (Jonian Sea, Mediterranean). The study of the shell morphology and anatomical soft parts of these specimens has revealed fundamental differences compared with the native, mostly Patellidae, species. Further observations of the morphology of the radula led to the provisional identification of the newly introduced limpet as a Lottiidae, tentatively a *Lottia* sp. A more precise species identification was not achieved, and will need to await ongoing DNA sequencing and further comparative studies. The new record of an introduced species for the Mediterranean is the first limpet so recognized, and the species appears to be represented by a range of sizes, implying that is well established along the intertidal Sicilian rocky-shores and is successfully recruiting in this region.

KEY WORDS

Species introduction; new record; invasive species; biogeography; Gastropoda; Mollusca.

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INTRODUCTION

The discovery from Italian shores of a limpet whose shell features clearly differed from the about 10 known Mediterranean limpet species, all of which belong to Patellidae Rafinesque, 1815 and one to Lottiidae Gray, 1840 (CLEMAM, 2016), led us to conclude that this was an introduced exotic species of Lottiidae not yet recorded from the Mediterranean. Our molecular investigations are still ongoing, but here we report the occurrence of this newly introduced species and present shell, radula, and morphological evidence for our assignment to Lottiidae, and tentatively to the genus *Lottia* Gray, 1833.

True limpets are assigned to Patellogastropoda Lindberg, 1986, whose members have a different shell geometry and microstructure and morpholo-

gical distinctions in gills, pericardial structure, and alimentary system (reviewed by Lindberg, 1988). Most authorities now follow Ponder & Lindberg (1996; 1997) in considering patellogastropods a monophyletic taxon that is either sister taxon to all other extant gastropods (e.g., Lindberg, 1998) or is at least a distinctive clade of gastropods whose higher phylogenetic position has been somewhat unstable in molecular analyses (Nakano & Sasaki, 2011; Zapata et al., 2014). Within patellogastropods, Patellidae is characterized by an anti-tropical distribution (Koufopanou et al., 1999) and this family has been considered the monophyletic sister taxon of all other extant patellogastropods (Lindberg, 1988; Lindberg & Hedegaard, 1996) or as sister taxon to all other patellogastropods except for Eoacmaeidae Nakano & Ozawa, 2007 (ibid.). Although patellogastropods exhibit more variation

in shell microstructure than all other gastropods combined (MacClintock, 1967; Lindberg, 1988), shell microstructure itself is known to be subject to phenotypic plasticity (Lindberg, 1998; Gilman, 2007) so is not an infallible indicator of phylogenetic affinity and this complicates the assignment of limpet fossil shells to extant families.

One of the most interesting aspects of the evolutionary history of patellogastropods is the striking restriction of different families to specific geographic regions (Powell, 1973; Lindberg, 1986; Lindberg, 1988; Koufopanou et al., 1999; Nakano & Ozawa, 2007; Reisser et al., 2012). Radiations of particular genera of limpets have been surprisingly restricted to particular ocean basins, probably reflecting the relatively short planktonic duration of the typically lecithotrophic larval stage of limpet genera that have been studied (Amio, 1963; Rao, 1975; Wanninger et al., 1999; Wanninger, Ruthensteiner & Haszprunar, 2000; Kay & Emler, 2002; earlier references therein). The first known long-distance introduction of a patellogastropod is documented by Nakano & Espinoza (2010), who reported for the W-Africa a new alien *Cellana* from the Indian Ocean.

The northeastern Atlantic and Mediterranean is dominated by Patellidae, with Lottiidae represented by only two species, of which only *Tectura virginea* (Müller O.F., 1776) is inside the Mediterranean (Koufopanou et al., 1999). Conversely, the North Pacific is dominated by numerous species of Lottiidae, with only a single Patellidae species, the nearly extinct giant, *Scutellastra mexicana* (Broderip et G.B. Sowerby I, 1829), restricted to the vicinity of the Gulf of California, Mexico.

Patellogastropod taxonomy is confounded by the relatively simple shell geometry, convergent shell shape and sculpturing and impressive phenotypic plasticity. This has produced a confusing history of generic names first proposed to be geographical widespread, and later re-evaluated as groupings based on only superficial similarity. Even within species there can be striking variation. For example, there are many known cases of phenotypic plasticity that correspond to ecotypes characteristic of particular microhabitats or host associations. These can further confound identifications that are based only on shell morphology.

Seven families currently compose Patellogastropoda: Acmaeidae, Eoacmaeidae, Lepetidae, Lot-

tiidae, Nacellidae, Patellidae and Pectinodontidae (Nakano & Sasaki, 2011).

In European waters two species of Lottiidae are reported (CLEMAM, 2016): *Tectura virginea* and *Lottia testudinalis* (Müller O.F., 1776). Both were previously assigned to *Acmaea* Eschscholtz, 1833 but this genus and the family, Acmaeidae, is now restricted to relatively few North Pacific species. Instead, these two species are currently assigned to Lottiidae. *Tectura virginea*, the type species of *Tectura* Gray, 1847, appears to be a highly divergent monotypic lineage that has little to do with other Lottiidae species (Eernisse, unpublished). *Lottia testudinalis* has often been incorrectly referred to the genus *Tectura* but this species also occurs in the North Pacific (Lindberg, 1979) and is closely related to multiple other *Lottia* species there, based on mitochondrial DNA evidence (D.J. Eernisse, unpublished). Because all of its close relatives are also found in the North Pacific, this implies a geologically recent invasion of this species to the North Atlantic through the Arctic Ocean.

In the Mediterranean, there is also one alien species of Cellanidae, *Cellana rota* (Gmelin, 1791), which is somewhat similar to Lottiidae in general shell characters. However, besides the shell and anatomical differences associated with limpets in this family when compared with Lottiidae, *C. rota* is common only along the extreme eastern coasts of the Mediterranean.

Here we report for the first time the discovery of a species of *Lottia* in the Mediterranean. The new alien species was assigned to Lottiidae on account of the presence of a single ctenidium (compared with none in Patellidae), the absence of the rachidian tooth in the radula and reduction of the marginal. The population of this new alien species seems well established along the eastern rocky-shore of Sicily in the vicinity of Catania. We suspect that the present finding is due to a human-mediated introduction because this relatively striking species was never reported previously anywhere in the Mediterranean. Whether this species has entered through one of the two most important allochthonous species entrances, the Strait of Gibraltar or the Suez Canal, is unknown.

Because of the difficulties inherent in the identification of lottiid species and because the family is still poorly known in many parts of the world, the geographical origin of the Mediterranean invader is

unfortunately still unknown. Our attempts to use existing literature on Lottiidae to identify this species confidently has been problematic. There are some other morphologically similar species found in the Caribbean, Eastern Pacific, Japan, and Oceania, but we have so far found contrary evidence discounting each of the species known to us from these regions as a satisfactory match. Although our identification to species is still in doubt, we suspect that our ongoing activities to undertake DNA sequencing could at least help narrow our identification to a specific species group and geographic region. One of us (DJE) has observed that Lottiidae species tend to cluster together in regional monophyletic groupings (D.J. Eernisse, unpublished observation), so sequences could help reveal where to look. For all these reasons and because the radula features have allowed us to make a tentative generic assignment, we refer to the new alien Lottiidae for now simply as *Lottia* sp., awaiting sequencing of other studies for a more precise identification.

ABBREVIATIONS. DEC: Douglas Eernisse collection (California, USA); DSC: Danilo Scuderi collection (Catania, Italy); HMC: Henk Mienis Collection (Tel Aviv, Israel).

MATERIAL AND METHODS

After the finding of a single unrecognized limpet shell near the southern branch of the harbour of Catania, Sicily, a more thorough sampling was undertaken between the harbour of Catania to the rocky artificial substrates of Messina, almost 150 km away from Catania. We only found this species of *Lottia* in localities close to Catania, within about 5 km from the harbour. Two collecting methods were followed: collection of specimens by hand from the rocky substrates in the intertidal environment and a visual census method without removing specimens from the substrate. The hand-collected material yielded 55 living specimens between January and August 2015 (DSC and DEC), while almost 150 specimens were observed with the visual census sampling during the same period. Representative specimen vouchers will be deposited in appropriate museums following our ongoing molecular studies.

For morphological analysis, shells were measured and shell shape was studied after removing the soft body from each specimen's shell. Radular composition as well as the external soft body parts were observed with a stereoscope and documented by photographs and drawings. Some individuals were preserved in ethanol and the related shells were numbered, photographed, and separately process or stored for ongoing DNA studies. Some shells of *C. rota* from Israel (HMC) were studied for comparisons.

RESULTS

Lottia Gray, 1833

Type species: *Lottia gigantea* Sowerby, 1834

Lottia sp.

EXAMINED MATERIAL. Catania, eastern coast of Sicily, 30 living specimens, intertidal breakwater of the harbour and 15 living specimens along the northern rocky shore of the city (DSC).

DESCRIPTION. Medium size: typical length 16 mm, height 5 mm (maximum 18.2 mm length and 7.0 mm height). Shell patelliform, relatively flat but some what conical, moderately solid (Figs. 1–8). Profile medium-high, aperture oval. Anterior slope slightly concave, not very steep; apex in the anterior third (Fig. 8). Dorsal sculpture has about 35–45 major ribs, almost flat, each alternated by 2–4 narrower and not very marked ribs (Fig. 9). Numerous concentric growth lines can be detected between ribs, more marked on young shells. A few nodules are sometimes present on uneroded shells at the intersections of ribs. External colour cream with dark radial lines (Figs. 1–3). Internal side shiny, opalescent, not metallic as in Patellidae, with intermediate area pale cream to azure, almost ochre to dark brown on the central area (Fig. 4). The external dark lines become visible through the otherwise translucent shell toward the margin, where a dark marginal band, alternated with whitish stains, encircles the aperture (Fig. 4).

Foot round and whitish (Fig. 10); attachment muscles whitish with few dark stains. A single ctenidium is found in the nuchal portion of the mantle cavity (Fig. 12), and there is no branchial cordon (secondary gill) as found in some other patellogastropods. Mouth and lateral side of cephalopod.

alic tentacles orange but otherwise white (Fig. 11). Snout and head pale purplish (Fig. 11). External side of the edge of mantle yellowish, internal side pale but bright green (Fig. 13). Marginal mantle tentacles short and fine, about 0.2 mm in length, numerous (Fig. 13). Radula with one pair of uncini per row (Fig. 14); first lateral teeth pointed, second lateral teeth broad and rounded, third lateral teeth slightly reduced and rounded; ribbon segment almost elongated (Figs. 14–15).

VARIABILITY. Size of shell ranges from 15 to 18 mm in length, 12–16 mm wide and 4 to 7 mm high. Colour variations of dorsal shell surface usually with whitish striped by dark radial lines, sometimes coalescing to form mottled markings (Figs. 3, 6), to almost uniformly dark (Fig. 5). Internal central area can be uniformly whitish (Fig. 7) or completely brown-black (Fig. 5, left). The continuous band along the internal margin of the shell can be uniformly dark (Fig. 5, right), or rarely the entire specimen is whitish with a few brown strips (Fig. 6). Sculpture can be faint or eroded in some specimens.

DISTRIBUTION. In the Mediterranean the species is known only from the above-mentioned material, representing the first record for this basin. The original geographical distribution remains unknown pending successful identification.

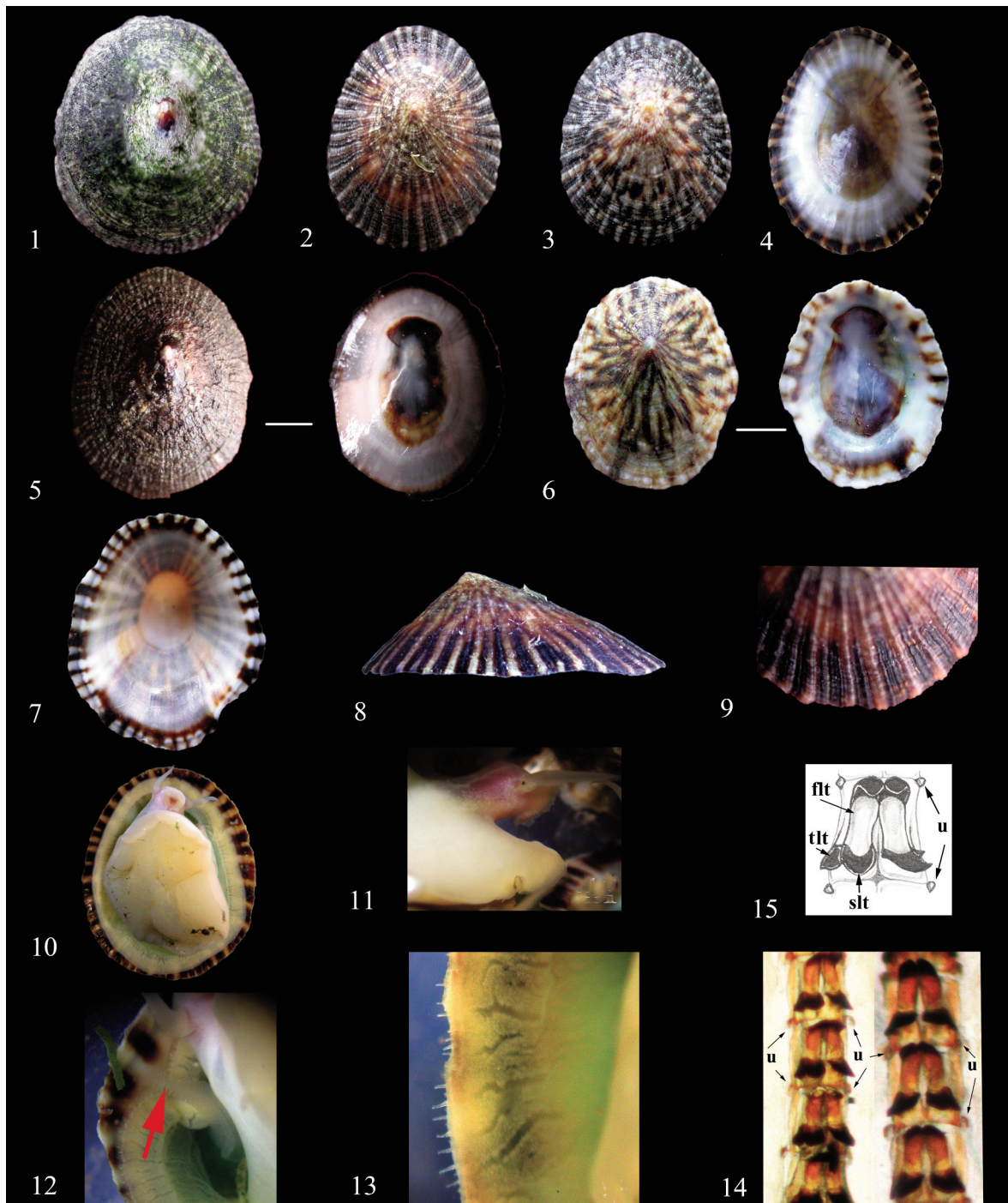
DISCUSSION

Based on the reported variation from the literature of morphological characters of the shell, external soft parts, and radula of Mediterranean patellogastropod species, we identified this newly discovered species as not only distinct from any of the known limpet species, but also as a member of a family, Lottiidae, which is nearly absent from the region. However, this left the challenge of a specific identification of this species, and members of Lottiidae worldwide are still poorly known and their taxonomy is notorious for its difficulty. At a higher level, they are especially distinguished by the presence or absence of a primary ctenidium or accessory (secondary) gill-like structures between the mantle edge and the foot known as a branchial cordon, characteristic layers of their shell, and radular tooth arrangement. Lottiidae have a ctenidium and generally lack secondary gills, among other fea-

tures. At a species level, members of Lottiidae are distinguished by their shape including position of the apex and lateral profile, fine details of their shell sculpture, their shell colour to some extent, their radular teeth arrangement, and characteristics (including colour) of external soft parts, although poorly documented for most species. Intraspecific variability for the characters mentioned is known. In order to identify this exotic species, we focused our studies on the group of Lottiidae characterized by a subcentral (only slightly anterior) apex, broadly oval profile, weak but definite rib sculpturing, shells drab with long dark stripes, whitish animals almost entirely lacking pigmentation except for parts of the head, and radula with almost elongated lateral teeth.

Following here are species to which the Mediterranean alien limpet, tentatively identified as a *Lottia*, has been compared. We have focused on *Lottia* species of medium size with sculpture, if not eroded, with major ribs that often are interspersed with up to two minor ribs, apex subcentral, with straight anterior slope, papillae extending distally from mantle attachment to shell small, fine, short, and well spaced compared to many other members of the genus; colouration of shell with alternating whitish and dark radial stripes. The only European species which shows only slight resemblance to the Mediterranean invader *Lottia* sp. is *L. testudinalis*, a cold-water circumboreal species, distributed between the northern part of the United Kingdom, the northwestern Atlantic as far south as about Cape Cod, and also known from subtidal depths off the Aleutian Islands, Alaska, in the northern Pacific Ocean (Lindberg, 1979). But the apex of *L. testudinalis* is more central, and the species found on Sicilian shores lacks its numerous finely beaded riblets. The living animal of *L. testudinalis*, which is known only from the cooler waters of higher latitudes, also seems more deep yellow in colour, and the radular teeth are differently arranged. Plus, its habitat is different; it does not occur in the subtidal and has not been observed on seaweeds, unlike *L. testudinalis*.

Among the many northeastern Pacific Lottiidae species, the only one with similar features including ribs is *L. pelta* (Rathke, 1833), and the “brown” and “coralline” forms are in particular somewhat similar (Lindberg, 1981). But compared to the Mediterranean invader, *L. pelta* has broader and knobbier



Figs. 1–15. *Lottia* sp., Catania, Sicily. Fig. 1: dorsal view of the shell (length 18.2 mm), harbour of Catania. Figs. 2–4: San Giovanni Li Cuti, Catania; dorsal view of the shell, length 15.1 and 13.2 mm (Figs. 2, 3); internal side of the shell (Fig. 4). Fig. 5: entirely blackish specimen (length 15.0 mm), San Giovanni Li Cuti, Catania. Fig. 6: paler specimen with mottled dark drawings (length 12.8 mm), harbour of Catania. Fig. 7: internal side of a specimen with whitish central area (length 16.8 mm), harbour of Catania. Figs. 8–14: San Giovanni Li Cuti, Catania; lateral view of the shell (Fig. 8); detail of the shell sculpture, length 16.8 mm (Fig. 9); ventral view of a living specimen, length 15.0 mm (Fig. 10); lateral view of a living specimen (Fig. 11); detail of the ctenidium (red arrow) (Fig. 12); detail of the edge of mantle, with mantle tentacles (Fig. 13); radular teeth in dorsal view (right) and in slightly tilted view (left) to show uncini (u) (Fig. 14); Fig. 15: drawing of radular teeth (flt: first lateral tooth; slt: second lateral tooth; tlt: third lateral tooth; u: uncini).

ribs, which deform the shell margin with weak scalloping. True ribs are also present in *Lottia gigantea* (Sowerby, 1834), but this species is completely different, for example with an anterior apex and completely different colouring of the living animal, with black head, tentacles and margin of foot. Many of the other members of *Lottia* differ in having fine riblets (not ribs) and different radula arrangement. One of us (DJE) is familiar with most of the East and North Pacific species and none of the species there seems to match it well.

Western Atlantic species share with the Mediterranean alien species more similar characters in dimensions, shell, external soft parts and radular morphology. Compared to the Mediterranean *Lottia* spp., *L. subrugosa* (d'Orbigny, 1846) is the most similar among Western Atlantic species, common along the Brazilian coasts, south to Uruguay. The size, colour and apex position of the shell seem to be similar to the Mediterranean alien species. But, judging from the original description of the species the shell sculpture seems somewhat different, characterized by large flattened axial ridges, which give the margin of the shell a winding outline. Compared to the description and pictures by Righi (1966), the radular teeth seem arranged in the same way. Two other species that are similar to *L. subrugosa*, *L. noronhensis* (E.A. Smith, 1890) and *L. marcusii* (Righi, 1966), also seem unlikely because of their extremely restricted geographical distribution, i.e. the Island of Fernando de Noronha Brasil, and that of Trinidad, respectively. Other similar Western Atlantic species are *L. jamaicensis* (Gmelin, 1791) and *L. leucopleura* (Gmelin, 1791), which however are characterized by more robust and prominent ribs. Another undetermined Atlantic species, called *Lottia* morph B, is reported from Nevis, Leeward Islands (Caribbean) (Hewitt, 2008), and resembles the Mediterranean invader in general shape, but is characterized by numerous and almost equally thin riblets on the shell.

Species of the western Pacific regions, including Australia, New Zealand, and southeastern Asia, were compared with available literature, but no close matches were found to the alien Mediterranean species. For example, *Notoacmea corrorenda* (May, 1920) is perhaps the most similar of these in shell morphology, but differs in its more flattened shell, smaller size, coarser sculpture, and different radular tooth arrangement.

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