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Biogeographical homogeneity in the eastern Mediterranean Sea - I: the opisthobranchs (Mollusca: Gastropoda) from Lebanon

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Abstract

A review of opisthobranch species from Lebanon (eastern Mediterranean Sea), based on literature records (scattered throughout various papers published over a period of more than 150 years) and recently collected material (1999-2002 within the CEDRE framework and other samples), is presented, yielding a total number of 35 taxa identified to species level. Special emphasis has been placed on alien species, for which scattered notes are also given. The known opisthobranch biota is composed of 22 native (~ 63%), 12 alien (~ 34%) and one cryptogenic (~ 3%) taxa. Eleven of these (*Berthella aurantiaca*, *Berthella ocellata*, *Aplysia fasciata*, *Felimare picta*, *Felimida britoi*, *Felimida luteorosea*, *Felimida purpurea*, *Phyllidia flava, Dendrodoris grandiflora*, *Dendrodoris limbata* and *Aeolidiella alderi*) constitute new records for the Lebanese fauna, whilst the examined material of a further seven species (*Elysia grandifolia*, *Pleurobranchus forskalii*, *Aplysia dactylomela*, *Bursatella leachii*, *Syphonota geographica*, *Goniobranchus annulatus*, *Flabellina rubrolineata*), anecdotally cited from Lebanon on the basis of the samples studied here, is explained for the first time. One additional taxon belonging to the genus *Haminoea* has been identified to genus level only.

Keywords: Mediterranean Sea, Lebanon, Mollusca, Opisthobranchia, alien species, cryptogenic species.

Introduction

During the last decades, due mostly to the opening of the Suez Canal, aquaculture and ship transport, hundreds of alien species have established themselves in the Mediterranean Sea (Galil, 2009; Zenetos *et al.*, 2012). To date, the bulk of the introduced organisms in the basin (> 70%) are thermophilic species of Indo-Pacific origin, coming from the Red Sea either stepwise through the Suez Canal ("Lessepsian migration" in the most restricted sense) or as one-jump larvae or adults (Gofas & Zenetos, 2003). Mostly confined to the easternmost Levantine shores for decades, several Erythrean species are currently spreading further to its western and northern parts, encouraged by the general warming of the Mediterranean Sea (Occhipinti-Ambrogi, 2007).

The number of alien species invading the Mediterranean Sea is now continuously increasing, particularly in the eastern basin. After the first general review published by Zibrowius (1992), a growing literature on the subject has been published in recent years (e.g.: Galil, 2009; Zenetos *et al.*, 2012). Molluscs are one of the major groups in the marine fauna worldwide and the first contributors to the alien fauna in the Mediterranean Sea (Zenetos *et al.*, 2010, 2012). Among them, opisthobranchs are a diverse group of specialized gastropod molluscs and important components of benthic marine ecosystems, exhibiting a wide range of food and defensive strategies (Cervera *et al.*, 2004). To date, more than 500 species of opisthobranchs are listed as recorded from the Mediterranean Sea (Gosliner *et al*., 2008; Templado & Villanueva in Coll *et al.*, 2010), of which ~ 30 species are exotic. Despite the Mediterranean molluscan fauna being commonly considered as the best known in the world (Oliverio, 2003), our general knowledge of the Levantine area still remains considerably poor due to lack of recent comprehensive studies, especially on opisthobranchs, and most of the current knowledge on the opisthobranch fauna of the Levant Sea originates from very sparse records. A comprehensive list of the opisthobranchs from Lebanon is currently missing, and data on distribution, taxonomy and ecology are scattered throughout various papers published over a period of more than 150 years. In fact, with the exception of a few papers from the early XIX and XX centuries (e.g. Puton, 1856; Pallary, 1912, 1919, 1938; Gruvel & Moazzo, 1929; Moazzo, 1931), during the last eighty years hardly a dozen papers, notes, abstracts and non peer-reviewed articles marginally cited opisthobranch species from

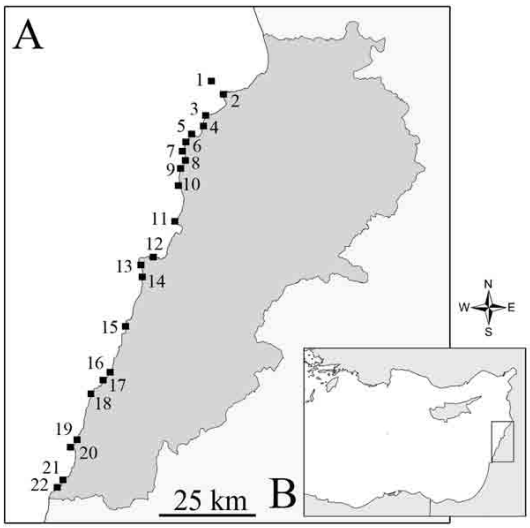

Fig. 1: Study area. A. Map of the sampling sites corresponding to localities reported in Appendix 1. B. The eastern Mediterranean Sea, with location of Lebanon.

Lebanon, without offering wider discussions (Spada, 1971; Fadlallah, 1975; Bogi & Khairallah, 1987; Bogi & Giannini, 1990; Bitar, 1996, 2013; Bitar & Kouli-Bitar, 1998; Valdés & Templado, 2002; Yokeş & Rudman, 2004; Zenetos *et al.*, 2004; Malaquias & Reid, 2008; Crocetta & Galil, 2012). Based on the material collected within the CEDRE framework (French-Lebanese co-operation programme 1999-2002: Zibrowius & Bitar, 2003; Morri *et al.*, 2009), enriched by recent records provided by one of the authors (G.B.), and by a careful review of the literature data, the aim of this paper is to gather all available data to provide the first complete compilation of Opisthobranchia from the Lebanese shores, placing special emphasis on alien species and including comments on some records previously published as personal communications or personal observations, or cited in conference proceeding abstracts only.

Materials and Methods

Bibliographic data

An extensive literature survey has been conducted. Indexed papers were searched, but an attempt to cover the grey literature as much as possible (i.e. non peer-reviewed and/or non indexed papers) has also been performed: most of the historical journals are not indexed, and malacological records are still being published in non indexed journals. Literature record listing has been as exhaustive as possible, regardless of each record referring to an independent finding, and collected data were re-analysed and taxonomically adjusted to allow for comparisons. In addition, the availability of all taxon names introduced from the area has been checked.

Sampling

Several localities have been sampled by two of the authors (G.B and H.Z.) between 1999 and 2002, and this material was later enriched by additional samples, photos and personal observations provided by one of the authors (G.B.). Sampling was carried out by hand collection during snorkelling and SCUBA diving in daylight hours only, and includes highly diverse habitats of almost all the different biotopes available from the intertidal and sublittoral down to a depth of ca. 40 m. Opisthobranchs were found at 22 sites, listed in Appendix 1 (see also Figure 1).

Laboratory work and updated taxonomy and nomenclature

In the case of preserved material, upon arrival at the laboratory, soft part samples were soon fixed in 2% buffered formaldehyde and then transferred to 70-75% EtOH; they are currently preserved at the Natural History Museum of Los Angeles Country (LACM) and Museo Nacional de Ciencias Naturales of Madrid (MNCN), whilst shelled sampled were dried and stored at Dipartimento di Biologia e Biotecnologie "Charles Darwin" - University of Rome "La Sapienza" (BBCD). Identifications have been done by three authors (G.B., F.C. and J.T.) up to species level where possible. Updated taxonomy and nomenclature used follow WoRMS (Appeltans *et al*., 2013).

Results

A total of 35 species of Opisthobranchia, representative of 16 families, have been reliably checked from Lebanon and reported or identified to species level, whilst a further one is cited as *Haminoea* sp., pending records of living specimens or a general and comprehensive taxonomical review on the genus, including diagnostic characters of the shells. The cumulative list of opisthobranch species from Lebanon, resulting from the critical analysis of literature records and new material examined herein is reported in Table 1. The details of the bibliographic reference, the taxonomic status and the material examined for each species are given in Appendix 2.

The known opisthobranch biota is composed of 22 native (~ 63%), 12 alien (~ 34%) and one cryptogenic (~ 3%) taxa. According to this survey, 11 species represented new records for the Lebanese fauna (*Berthella aurantiaca*, *Berthella ocellata*, *Aplysia fasciata*, *Felimare picta*, *Felimida britoi*, *Felimida luteorosea*, *Felimida purpurea*, *Phyllidia flava, Dendrodoris grandiflora*, *Dendrodoris limbata* and *Aeolidiella alderi*). Additionally, we have checked the actual material of a further seven species, which were previously published from Lebanon without clear reference to specific samples (*Elysia grandifolia*, *Pleurobranchus forskalii*, *Aplysia dactylomela*, *Bursatella leachii*, *Syphonota geographica*, *Goniobranchus annulatus*, *Flabellina rubrolineata*).

Finally, we did not include *Chelidonura fulvipunctata* Baba, 1938 among confirmed records: it was reported from Lebanon by Tsiakkiros & Zenetos (2011) on the basis of the reference "Lakkis & Novel-Lakkis, 2005", that evidently referred to a MEDCORE Power Point presentation (freely available on the web at http://www.medcore.unifi.

it/conference/PDFComunicazConvegno/3-LAKKIS%20SEDIMENT%20%20Firenze.pdf). No specific records of molluscan species were ever published in any of that meeting's Abstracts [see Lakkis (2005) and Lakkis & Novel-Lakkis (2005)], whilst the MEDCORE Proceedings' paper only dealt with algae living in vermetid platforms along the Lebanese shores (Lakkis & Novel-Lakkis, 2006) and has never been followed by any paper on the Lebanese molluscs. Therefore, the molluscan records in the Power Point presentation are deemed to be unreliable.

Discussion

The 35 species listed here represent a particularly poor fauna, accounting for less than 7% of the known Mediterranean Opisthobranchia (Templado & Villanueva in Coll *et al.*, 2010). A higher number of opisthobranch species was expected from the Lebanese shores, based on the data available from better studied eastern Mediterranean countries such as Turkey (approx. 100 species: Yokeş, 2009; Yokeş *et al.*, 2012; Tural & Yokeş, 2012) and Israel (>50 species: e.g. Barash & Danin, 1971, 1977, 1982, 1986). Admittedly, our Lebanese data are based on an inappropriate sampling methodology for this group of molluscs, since our new opisthobranch material in particular originates from general sampling of benthic marine species and communities. Therefore, many tiny and cryptic species might have been overlooked, and the lack of specific surveys focused on opisthobranchs (which require special sampling methods, live collection in their habitat, including sampling at night, and observation before fixation) may have hampered exhaustive work. However, relatively poor knowledge on the fauna of the Levant basin, and especially of the north-eastern part, has previously been stressed by several authors (Harmelin *et al.*, 2007, 2009; Vacelet *et al.*, 2007; Morri *et al.*, 2009, among others), and our data definitively confirm such gaps.

The 22 native species account for approx. 63% of the known Lebanese opisthobranch fauna, and the new records reported point to the importance of focused field studies covering also opisthobranchs. All these species, however, were already known in the eastern Mediterranean Sea from Turkey and Israel (Swennen, 1961; Barash & Danin, 1971, 1982; Gat & Fainzilber, 1983; Cattaneo-Vietti *et al.*, 1990; Yokeş, 2009).

On the contrary, 12 of the opisthobranch species re-

Table 1. Opisthobranch species from Lebanon, with bibliographic records (BR) and material examined (ME). **Bold**: alien species in the Mediterranean Sea (see Appendix 2).

Taxa	BR	ME	Taxa	BR	ME
Family ACTEONIDAE d'Orbigny, 1843			Family APLYSIIDAE Lamarck, 1809		
Acteon tornatilis (Linnaeus, 1758)	X		***Aplysia dactylomela* Rang, 1828**	X	X
***Pyrunculus fourierii* (Audouin, 1826)**	X	X	*Aplysia depilans* Gmelin, 1791	X	X
Retusa mammillata (Philippi, 1836)	X		*Aplysia fasciata* Poiret, 1789		X
Retusa truncatula (Bruguière, 1792)	X		***Bursatella leachii* Blainville, 1817**	X	X
Family RHIZORIDAE Dell, 1952			***Syphonota geographica* (A. Adams & Reeve, 1850)**	X	X
Volvulella acuminata (Bruguière, 1792)	X		Family CHROMODORIDIDAE Bergh, 1891		
Ringicula auriculata (Ménard de la Groye, 1811)	X		*Felimare picta* (Schultz in Philippi, 1836)		X
Ringicula conformis Monterosato, 1877	X	X	*Felimida britoi* (Ortea & Perez, 1983)		X
Family BULLIDAE Gray, 1827			*Felimida luteorosea* (Rapp, 1827)		X
Bulla striata Bruguière, 1792	X	X	*Felimida purpurea* (Risso in Guérin, 1831)		X
Family HAMINOEIDAE Pilsbry, 1895			***Goniobranchus annulatus* (Eliot, 1904)**	X	X
Haminoea hydatis (Linnaeus, 1758)	X		***Hypselodoris infucata* (Rüppell & Leuckart, 1831)**	X	X
Haminoea sp.		X	Family DISCODORIDIDAE Bergh, 1891		
Family CYLICHNIDAE H. Adams & A. Adams, 1854			*Tayuva lilacina* (Gould, 1852)	X	X
***Acteocina mucronata* (Philippi, 1849)**	X	X	Family PHYLLIDIIDAE Rafinesque, 1814		
Cylichna cylindracea (Pennant, 1777)	X		*Phyllidia flava* Aradas, 1847		X
***Cylichnina girardi* (Audouin, 1826)**	X		Family DENDRODORIDIDAE O'Donoghue, 1924		
Family PLAKOBRANCHIDAE Gray, 1840			*Dendrodoris grandiflora* (Rapp, 1827)		X
***Elysia grandifolia* Kelaart, 1857**	X	X	*Dendrodoris limbata* (Cuvier, 1804)		X
Family UMBRACULIDAE Dall, 1889			Family POLYCERIDAE Alder & Hancock, 1845		
Umbraculum umbraculum (Lightfoot, 1786)	X	X	***Plocamopherus ocellatus* (Rüppell & Leuckart, 1831)**	X	X
Family PLEUROBRANCHIDAE Gray, 1827			Family AEOLIDIIDAE Gray, 1827		
Berthella aurantiaca (Risso, 1818)		X	*Aeolidiella alderi* (Cocks, 1852)		X
Berthella ocellata (delle Chiaje, 1830)		X	Family FLABELLINIDAE Bergh, 1889		
***Pleurobranchus forskalii* (Rüppell & Leuckart, 1831)**	X	X	***Flabellina rubrolineata* (O'Donoghue, 1929)**	X	X

corded from Lebanon are alien (approx. 34%), a proportion higher than the range of 10-20% commonly estimated for the entire Levantine fauna (Zenetos *et al.*, 2010). Eleven are well-known invaders (*Pyrunculus fourierii*, *Acteocina mucronata*, *Cylichnina girardi*, *E. grandifolia*, *A. dactylomela*, *B. leachii*, *S. geographica*, *G. annulatus*, *Hypselodoris infucata*, *Plocamopherus ocellatus* and *F. rubrolineata*), and some were detected as widespread for decades, such as *C. girardi* and *B. leachii* (see Remarks in Appendix 2). This is mostly the case of shelled, larger-sized and/or easy-to-identify species, which lack morphologically similar native Mediterranean counterparts or have been recorded earlier based on empty shells found in bioclastic sediments. In addition, the alien spreading of *B. leachii*, *A. dactylomela* and *S. geographica* in the Mediterranean is outstanding: the three species having been able to colonize the central part of the basin (Crocetta, 2012), with scattered records of the former up to the western part (Ibáñez-Yuste *et al.*, 2012). Conversely, other species have only recently formed established populations in the eastern Mediterranean, such as *G. annulatus*, *E. grandifolia*, *F. rubrolineata* and *A. dactylomela* (see Remarks in Appendix 2), and therefore, the Lebanese records only fill some gaps in their known Mediterranean expansion. However, among these, the presence of *P. forskalii* deserves attention. It was known from the Mediterranean Sea based on the isolated record of two specimens in 1974 from Israel (Barash & Danin, 1977), and its recent presence along the Lebanese shores suggests that further field research may lead to the discovery of established populations in the eastern part of the basin.

The high proportion of recorded alien species leads to interesting conclusions. There has been some debate, in recent years, on which life-history traits make a species an invader or a successful colonizer, often in peculiar environments (review in Morton, 1997). Aliens have been assumed to be typical opportunistic species, although exceptions have been highlighted by other authors (Gofas & Zenetos, 2003). Indeed, plastic responses to resources, natural enemies, and the physical environment all determine the ability of a species to invade. However, the group of gastropods on which we have focused represents an exception to this generalization, with most species exhibiting very specific dietary requirements and specialized defensive strategies. Unfortunately, not much information is available on biotic factors determining the ability of the alien opisthobranch species to invade new regions. According to Mollo *et al.* (2008), who studied three well known and established Mediterranean invaders (*Haminoea cyanomarginata*, *S. geographica* and *Melibe viridis*), selective dietary requirements (to obtain protective chemicals) may act as limiting factors to the migration of alien opisthobranch species, while the non-selective nature of their feeding habits, related to the ability to biosynthesise *de novo* defensive metabolites, represents a predisposing factor for colonizing new environments. This strongly suggests that only the most 'efficient' species may be able to invade, and this would also explain the low number of confirmed alien opisthobranchs recorded in the Mediterranean Sea (~ 30) relative to the total number of ca. 200 alien molluscan species (Zenetos *et al.*, 2012). However, only some of these are now considered well established (Zenetos *et al.*, 2010; Crocetta *et al.*, 2013), with multiple records from all over the Mediterranean Sea and/or massive presence in some areas, whilst others (e.g. *Halgerda willeyi*, *Dendrodoris fumata*, *Cuthona perca*, *Caloria indica*, *Baeolidia moebii*) were recorded in the Mediterranean Sea by only one or few very isolated specimens (Barash & Danin, 1986; Perrone, 1995; Gat, 1993; Turk, 2000; Turk & Furlan, 2011) and might be considered as ephemeral entries, especially when their records date back several decades.

Finally, the short- and medium-term fate of the marine molluscan fauna of the Mediterranean Sea depends on the species pools from which alien spreading taxa are drawn (mainly from Red Sea and West African coasts), as well as on the food resources in the recipient regions and on the anti-predatory strategies of the invaders (Vermeij, 2012). The current lack of evidence on species extinction in relation to the establishment of alien species is seemingly leading to increased species richness for global Mediterranean molluscan fauna (Briggs, 2006, 2010), and in turn the biodiversity increase may be perceived as a positive consequence of alien arrival and establishment, especially in the eastern basin (Galil, 2007). However, the spread of these species may lead to biotic alteration of both habitat structure and ecosystem processes (Boero *et al*., 2008). It is therefore evident that investments for a better understanding of the eastern Mediterranean fauna may yield outcomes of value for the entire Mediterranean marine biology. The coasts of Lebanon, one of the first areas where the Lessepsian migrants meet the Mediterranean biota, offer a wide range of potentially unique case studies, and are therefore an excellent natural laboratory where all these issues could be studied.

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