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"Opisthobranch" (mollusks) inventory of the Faro Lake: a Sicilian biodiversity hot spot

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Abstract
A census of the "opisthobranch" fauna in the Faro Lake and connected canals (NE Sicily) has been realized by photo documentation and specimen samplings, carried out monthly from February 2010 to the present. A total of 47 species have been reported, nine of which are cited in the historic and recent literature (from 1969 to 2016) vs. 38 first records; six were non-indigenous species. A major number of species, 16, was found exclusively in the lake with respect to the four species localized in the canals, whilst 10 were shared species. Based on the frequency of records, 24 "occasional", 20 "settled" and three "invasive" species have been distinguished; these latter included two non-indigenous species, *Aplysia dactylomela* and *Bursatella leachii*, plus the Mediterranean *Dendrodoris limbata*, whose recent introduction in the Faro Lake from other Mediterranean lagoons is here postulated.

Keywords: *Opisthobranchs, mollusks, Faro Lake, checklist, Mediterranean Sea*

Introduction

Brackish areas are known for high biodiversity tied to marine–continental gradients and environmental patchiness, which determine a wide range of micro-environments (Basset et al. 2008). Human impact has severely affected such environments, causing habitat fragmentation and, in turn, connectivity loss (Suchanek 1994; Lotze 2004; Lotze et al. 2006). Habitat modification, reduction and fragmentation are some of the most serious threats to biodiversity (Sih et al. 2000) and recognized as an important threat in the marine environment (Suchanek 1994; Gray 1997; Airoldi & Beck 2007).

The Faro Lake, although subject to high anthropic pressure, is now part of a Natural Reserve, "the Capo Peloro Lagoon", and is considered one of the most peculiar coastal basins around the Mediterranean (Leonardi et al. 2009). Its contribution to the biodiversity of Sicilian waters is probably high, but historical checklists are lacking, except for some dated investigations, published in local magazines. Such literature data, compared with results of recent studies indicate that some major taxa, i.e. mollusks, showed a general decline in terms of biodiversity decrease and rarefaction of endemic taxa (Giacobbe 2012). Furthermore, an increased introduction of non-indigenous species (NIS) has been recorded in this lake and connected canals (Cosentino et al. 2009; Cosentino & Giacobbe 2011; Giacobbe 2012; Giangrande et al. 2012), and non-indigenous "opisthobranchs" have been reported with increased frequency (Cosentino et al. 2009; Giacobbe & De Matteo 2013; Malaquias et al. 2016). In this respect, the "sea slugs", a highly diverse group which includes potentially invasive species (Zenetos et al. 2010), have been monitored in the framework of the PRA program "Settlement dynamics and colonization of allochthonous assemblages in the Capo Peloro Lagoon".

The aims of the present contribution are: (i) to provide the first checklist of "opisthobranch" (here referred to as an informal group) fauna in the Faro Lake and connected canals; (ii) to define their local distribution with respect to the direct/indirect

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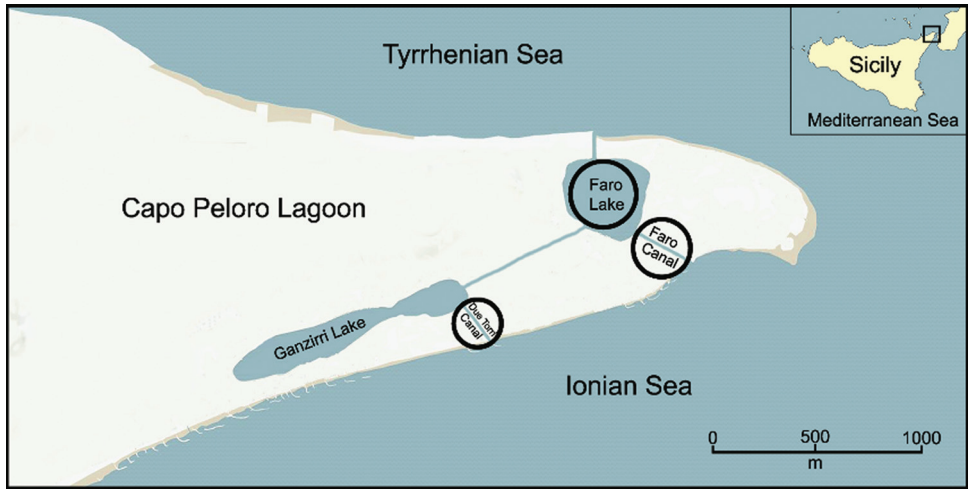

Figure 1. Area of "Capo Peloro Lagoon", north-east Sicily. Empty circles indicate sampling stations.

connection with the sea; (iii) to individuate the best-characterizing endemic and introduced taxa, in the framework of a long-term monitoring program.

Materials and methods

"The Capo Peloro Lagoon" is a brackish system located in the north-eastern point of Sicily (38° 15′57"N, 15°37′50" E) (Figure 1). It consists of two connected basins, Ganzirri and Faro, each of them communicating with the sea, by the "Faro canal" and "Due Torri canal", respectively. The whole lagoon receives significant marine inflows through the canals that are characterized by strong tidal currents, contrasting with the low hydrodynamics of both lakes. Anthropogenic pressure is high, due to human activities such as mollusk farming, and the high population density of the surrounding areas.

The Faro Lake covers an area of 263,600 m^2; it is the deepest coastal basin in Italy, reaching 29 m depth in the eastern part, while it does not exceed 3.5 m in the western. Such bathy-morphology is responsible for a peculiar meromictic regime, with anoxic waters below 10 m depth (Saccà et al. 2008). The Ganzirri Lake covers a 340,000-m^2 area, with a maximum depth of 7 m and a markedly brackish regime (Bottari et al. 2005); since it is very poor in "opisthobranch" fauna, which tend to be concentrated in the canal, it has been excluded from the present investigation.

The "opisthobranch" fauna has been surveyed monthly from February 2010 to the present, the first week of each month, by snorkeling to 2 m depth, and by SCUBA diving down to the oxic–anoxic transition layer, at 10 m depth. A total of 16 monitoring stations, by photo recording and specimen collection, have been selected as representative of the main substrate types within the explored area. Each station, identified by a code, geographical coordinates and depth, has been explored by means of a 25-m^2 grid, folded four times around a previously established central point, thus covering a 100-m^2 surface. *In situ* observations and related photographs have been reported on field protocols, noting the number of specimens for each species. The collected specimens were preserved in 95% alcohol and observed under a stereomicroscope for confirming identification.

Based on the respective frequency of records, each species was considered "occasional" (one record), "settled" (plus records through the whole investigation period) or "invasive" (very high numbers of individuals everywhere in the lake and/or canals, increasing in time), as reported in Table I; the source of first record (literature or present investigation) is also specified.

Results and discussion

A total of 47 species of sea slugs have been reported for the Faro Lake and connected canals, belonging to the orders Nudibranchia (11 families, 23 species), Sacoglossa (four families, four species), Anaspidae (one family, five species), Cephalaspidea (two families, eight species), Pleurobranchomorpha (one family, seven species) and Umbraculida (one family, one species) (Table I).

The Faro Lake had the highest number of species, 38, mostly Cephalaspidea and Nudibranchia, 16 of which were not found in the canals. Twenty-four

Table I. Updated checklist of "opisthobranchs" from Faro Lake.

Species		First record	Faro Lake	Faro channel	Due Torri channel
NUDIBRANCHIA	Cuvier, 1817				
Dorididae	Rafinesque, 1815				
Doris verrucosa	Linnaeus, 1758	N	2	2	2
Doris bertheloti	(d'Orbigny, 1839)	N	2	2	2
Tethydidae	Rafinesque, 1815				
Melibe viridis⋆	(Kelaart, 1858)	C	1		
Aeolidiidae	Gray, 1827				
Aeolidiella alderi	(Cocks, 1852)	N	2	2	2
Spurilla neapolitana	(Delle Chiaje, 1841)	N	2		
Polyceridae	Alder & Hancock, 1845				
Polycera quadrilineata	(O. F. Müller, 1776)	N	1	1	
Polycera hedgpethi⋆	Er. Marcus, 1964	E	2	2	
Kaloplocamus ramosus	(Cantraine, 1835)	N	2	2	
Proctonotidae	Gray, 1853				
Janolus cristatus	(Delle Chiaje, 1841)	N	1	1	
Scyllaeidae	Alder & Hancock, 1855				
Scyllaea pelagica	Linnaeus, 1758	N	1		
Flabellinidae	Bergh, 1889				
Flabellina affinis	(Gmelin, 1791)	N	2	2	
Flabellina pedata	(Montagu, 1816)	N	1	1	1
Flabellina lineata	(Lovén, 1846)	N	2		2
Calmella cavolini	(Vérany, 1846)	N	1		
Facelinidae	Bergh, 1889				
Cratena peregrina	(Gmelin, 1791)	N	1	1	
Facelinopsis marioni	(Vayssière, 1888)	N	1		
Dondice banyulensis	Portmann & Sandmeier, 1960	N		1	1
Chromodorididae	Bergh, 1891				
Felimare picta	(Schultz in Philippi, 1836)	N	1	1	
Discodorididae	Bergh, 1891				
Platydoris argo	(Linnaeus, 1767)	N	2		
Jorunna onubensis	Cervera, García-Gómez & García, 1986	N		2	2
Tayuva lilacina	(Gould, 1852)	N	2		2
Discodoris stellifera	(Vayssière, 1903)	N	1		1
Dendrodorididae	O'Donoghue, 1924 (1864)				
Dendrodoris limbata	(Cuvier, 1804)	N	3	3	3
SACOGLOSSA	Ihering, 1876				
Plakobranchidae	Gray, 1840				
Elysia timida	(Risso, 1818)	N	1		
Limapontiidae	Gray, 1847				
Ercolania viridis	(A. Costa, 1866)	N			1
Oxynoidae	Stoliczka, 1868 (1847)				
Oxynoe olivacea	Rafinesque, 1814	N	1		
Hermaeidae	H. Adams & A. Adams, 1854				
Hermaea variopicta	(A. Costa, 1869)	N	1		
ANASPIDAE	Fischer, 1883				
Aplysiidae	Lamarck, 1809				

(*Continued*)

Table I. (Continued).

Species		First record	Faro Lake	Faro channel	Due Torri channel
Aplysia fasciata	Poiret, 1789	N	2	2	2
Aplysia punctata	(Cuvier, 1803)	N	2	2	2
*Aplysia dactylomela**	Rang, 1828	B	2	3	3
*Bursatella leachii**	Blainville, 1817	C	3	3	3
Notarchus punctatus	Philippi, 1836	N	1		
CEPHALASPIDEA	P. Fischer, 1883				
Haminoeidae	Pilsbry, 1895				
Haminoea hydatis	(Linnaeus, 1758)	A	1		
Haminoea navicula	(da Costa, 1778)	A	1		
*Haminoea cyanomarginata**	Heller & Thompson, 1983	N	1		
Haminoea orteai	Talavera, Murillo & Templado, 1987	D	1		
Aglajiidae	Pilsbry, 1895 (1847)				
Aglaja tricolorata	Renier, 1807	F			2
Philinopsis depicta	(Renier, 1807)	N	1		1
*Chelidonura fulvipunctata**	Baba, 1938	G		2	2
Chelidonura africana	Pruvot-Fol, 1953	N			2
PLEUROBRANCHOMORPHA	Pelseneer, 1906				
Pleurobranchidae	Gray, 1827				
Pleurobranchus membranaceus	(Montagu, 1816)	N	1		
Pleurobranchaea meckeli	(Blainville, 1825)	N		2	2
Berthella stellata	(Risso, 1826)	N	1		
Berthella ocellata	(Delle Chiaje, 1830)	N	2		2
Pleurobranchus testudinarius	Cantraine, 1835	N		2	2
Berthellina edwardsii	(Vayssière, 1897)	N	2	2	2
UMBRACULIDA	Odhner, 1939				
Umbraculidae	Dall, 1889 (1827)				
Umbraculum umbraculum	(Lightfoot, 1786)	N			1

First records: Parenzan (1979) (A); Cosentino et al. (2009) (B); Giacobbe et al. (2010) (C); Giacobbe and De Matteo (2013) (D); Spinelli et al. (2015) (E); Malaquias et al. (2016) (G); species found and reported for the first time in this study (N).
Frequency of records: **1**, occasional species; **2**, settled species; **3**, invasive species.
Asterisk (*) indicates non-indigenous species.

species were recorded in the Due Torri canal, four of which did not occur elsewhere in the lagoon. The Faro canal provided 22 species, all shared with the other environments. A comparison of lake and canals based on species composition (Bray–Curtis similarity; presence/absence data) showed the highest similarity between the canals rather than between each canal and the lake (Figure 2).

This affinity did not change when a numeric value was assigned to the three categories: occasional

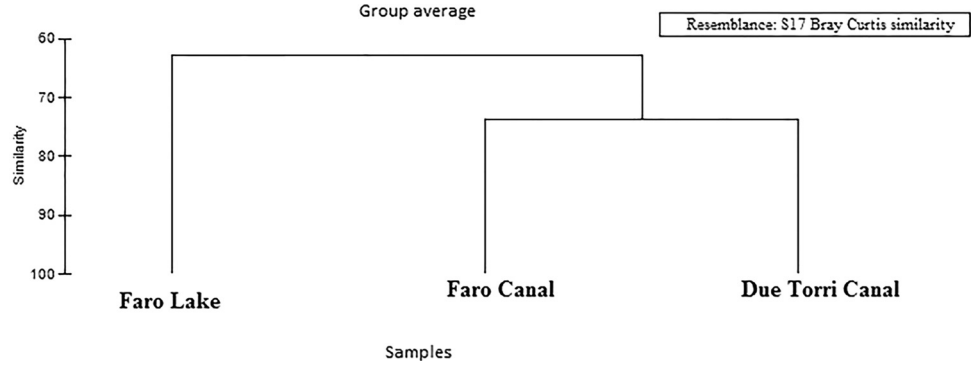

Figure 2. Bray–Curtis similarity between the species compositions (presence/absence data) of Faro Lake, Faro canal and Due Torri canal.

(value of 1), settled (2), invasive (3). Such distinct species composition well reflected the different hydrodynamics (high currents in the canals) and connection with the sea. The "settled" species, in fact, according to Cattaneo Vietti and Chemello (1991), were generally localized, since they were linked to proper environmental conditions (hydrodynamic, light, substrate, etc.) and food source (sponges, hydrozoans, etc.), whereas the "occasional" species, recruited from the close marine waters or introduced by aquaculture, might be hampered by competition and environmental variability.

The "shared" species, which have been recorded with different frequencies, included the "settled" *Berthellina edwardsi*, *Aeolidiella alderi*, *Doris bertheloti*, *Doris verrucosa*, *Aplysia fasciata* and *Aplysia punctata*, basic species which characterized the whole investigated area. A further three shared species occurred with very high frequency and abundance, showing an invasive behavior; they were the introduced *Aplysia dactylomela* and *Bursatella leachii* plus the Mediterranean *Dendrodoris limbata*. *Aplysia dactylomela* was reported for the lake before the present monitoring program (Cosentino et al. 2009), but only recently has it displayed an invasive behavior in the canals; *B. leachii* was previously known from the Strait of Messina (Giacobbe et al. 2010), later colonizing the lagoon areas. *D. limbata* represents a peculiar case, since it does not concern the native fauna of the lake although the species is widely distributed in Mediterranean transitional areas; the early records of this species in the Faro Lake date back to 2008, in association with the introduced calcareous sponge *Paraleucilla magna* and the serpulid polychaete *Branchiomma luctuosum* (S. Giacobbe, pers. comm.). Such an association perfectly reflected that illustrated in Longo et al. (2012) who reported the *P. magna* introduction in Mar Piccolo. We suggest that a complex benthic association, spreading in Mediterranean transitional waters by means of the mussel trade, recently reached and colonized the Faro Lake with high invasiveness. The related colonization processes, that overcome each seasonal trend, will be discussed in a further publication. It is noteworthy as two species, the Indo-Pacific *B. leachii* and the Mediterranean *D. limbata*, were almost simultaneously introduced in the lake, monopolizing the roles of benthic opportunistic deposit-feeder and spongivore, respectively. The other introduced species, namely *Polycera hedgpethi*, *Melibe viridis*, *Haminoea cyanomarginata* and *Chelidonura fulvipunctata*, did not show invasive behavior. A further suspected NIS, *Tayuva lilacina*, is provisionally considered a cryptogenic species, in agreement with Crocetta et al. (2013) and authors cited within.

The 47 reported species remarkably increased the number of "opisthobranch" taxa known for the whole "Capo Peloro Lagoon", which included nine species according to the historical (Parenzan 1979) and recent literature (Cosentino et al. 2009; Giacobbe 2012; Giacobbe & De Matteo 2013; Spinelli et al. 2015; Malaquias et al. 2016), namely *Haminoea orteai*, *Haminoea navicula*, *Haminoea hydatis*, *Polycera hedgpethi*, *Aglaja tricolorata*, *Aplysia dactylomela*, *Melibe viridis*, *Bursatella leachii* and *Chelidonura fulvipunctata*, whilst 38 species were first records (Table I), 10 of which were first records in Sicily: *Doris bertheloti*, *Jorunna onubensis*, *Polycera hedgpethi*, *Facelinopsis marioni*, *Dondice banyulensis*, *Scyllaea pelagica*, *Hermaea variopicta*, *Haminoea orteai*, *Chelidonura africana* and *Berthellina edwardsi*. The 47 species (24 "occasional", 20 "settled", and three "invasive") reported for the small Faro Lake represent a remarkable data set, with respect to the whole Mediterranean (248 "opisthobranch" species listed by Sabelli et al. 1990) as well as some regional inventories (35 taxa from Lebanon, in Crocetta et al. 2013). Such a high number of species is particularly impressive if compared with the "quite rich" "opisthobranch" fauna (more than 20 species) reported for the widest Sicilian lagoon, the "Stagnone di Marsala", by Cattaneo Vietti and Chemello (1991). In agreement with these authors, who also provided an exhaustive review of "Opisthobranch fauna present in Mediterranean lagoon waters", we note the literature is rich in records from transitional areas, but lacking in systematic investigations; for this reason, a Mediterranean biogeography of brackish "opisthobranch" fauna has not been assessed to date. At the same time, although marked latitudinal/climatic differences are expected, global warming and anthropogenic vectors push biological homogenization, through NIS introduction and simultaneous rarefaction of endemic taxa. In the Faro Lake, the seven ascertained NIS represent more than 14% of the local "opisthobranch" fauna, suggesting a high rate of introduction. The ecosystem vulnerability is testified by demographic explosions of *B. leachii*, one of the 100 worst invasive species in the Mediterranean (Streftaris & Zenetos 2006) and *A. dactylomela*, in the canals. By contrast, NIS apparently delay the basin colonization with respect to the close marine environments (Cosentino et al. 2009; Crocetta et al. 2009). A similar delay with respect to other

Mediterranean lagoons is probably tied to the local main vector of introduction, the mussel trade, having in the Faro Lake a marginal step-stone.

Conclusion

In conclusion, the present investigation remarkably increases the "opisthobranch" diversity of Faro Lake, which appears to be a biodiversity hot spot. The introduced species are a noteworthy percentage of the total "opisthobranch" fauna that dominate in abundance; between them, the potential invasiveness of some large-sized Anaspidaea, such as *Bursatella leachii* and *Aplysia dactylomela*, is confirmed. Furthermore, endemic Mediterranean species, such as *Dendrodoris limbata*, once introduced from other brackish areas showed invasive behavior, testifying to vulnerability in a human-impacted environment. It is evident that the wildlife including "opisthobranchs" of Sicily is not sufficiently known in relation to the forthcoming biogeographical changes, similarly to other major groups whose dynamics need an appropriate investigative effort.

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