

Biodiversity loss in Sicilian transitional waters: the molluscs of Faro Lake

Salvatore Giacobbe

Department of Biological and Environmental Sciences, Viale Ferdinando Stagno d'Alcontres, 31 - 98166 S.Agata-Messina, Italy;
e-mail: sgiacobbe@unime.it

ABSTRACT

Sediment samplings were carried out in six stations of Faro Lake (Sicily, Italy) during spring and autumn 1991, and spring 1993, 2006, 2010, to investigate the soft bottom mollusc assemblages. The study have provided the first quantitative data on the mollusc fauna of Faro Lake, to date known only for some dated inventories. Some differences in species composition in respect to the ancient literature were highlighted. The 1991-2010 data sets showed changes in the mollusc assemblages, which impoverished in composition and structure. Basic indices of community structure (S , d , H' , J') indicate a marked decline in the 2006, followed by a recovery period during 2010. The multivariate analysis, based on a the Bray-Curtis similarity index, proved that mollusc assemblages sampled prior to the 2006 crisis were more structured and spatially differentiated than those settled later. The observed decline of endemic taxa and the concurrent settlement of species introduced by mussel farming, make the mollusc assemblages in the Faro Lake a case-study for the effect of species introduction in confined environments.

KEY WORDS

Coastal ponds; Macrobenthic fauna; changing communities; endemisms; Alien species.

Received 12.05.2012; accepted 27.11.2012; printed 30.12.2012

Proceedings of the 1st International Congress "Insularity and Biodiversity", May 11th-13th, 2012 - Palermo (Italy)

INTRODUCTION

Transitional waters (TWs), since ecotones between terrestrial, freshwater and marine ecosystems, are characterized by highly dynamic processes, strong physical and chemical clines, and irregular temporal trends (De Wit, 2007; Evagelopoulos et al., 2009). These environments, that provide key ecosystem services, are characterized by high productivity levels, whose exploitation attracted human populations since the Palaeolithic Age (Knottnerus, 2005). Due to the long history of high anthropogenic pressure, European estuaries and coastal areas are among the most severely degraded systems worldwide (Lotze et al., 2006). The habitat loss, that between 1960 and 1995 reached a 50% rate (Airoldi & Beck, 2007), was also responsible of a large-scale

habitat fragmentation that reflected on the local/regional biodiversity levels. The rarefaction of keystone or engineer species, the extinction of endemic and rare taxa, the burst of pollution indicators, the spreading of introduced alien species, typically testify a biodiversity loss due to habitat depletion (Wolff, 1998; Levin et al., 2001).

In the recent years, increased conservation policies required more and more detailed information on the environmental quality of coastal and estuarine environments, with a particular emphasis towards the biological indicators (Borja et al., 2000). Nevertheless, the necessary background of knowledge on both the present and past biodiversity levels is often lacking, and reference conditions along the European coasts are not available (Ponti et al., 2008). Such evident information gap is particularly marked

for some Southern Mediterranean regions, whose TWs are partially or totally disregarded in the national reviews (Basset et al., 2006) as well as in the large-scale assessments (Munari & Mistri, 2010).

The Sicilian TWs include wetlands, semi-enclosed bays, brackish basins, coastal ponds, xero-Mediterranean lagoons, and marine lakes, submitted to different types and grade of anthropogenic pressure (Mazzola et al., 2010), whose impact on the local biodiversity is not still quantified. Furthermore, the present knowledge on the respective benthic assemblages are inappropriate for a spatio-temporal comparison, due to the different investigation methods and efforts, whilst historical data series (Leonardi & Giacobbe, 2001) are rarely available.

The Faro Lake, belonging to the “Capo Peloro e Laghi di Ganzirri” CSI and SPZ area (North-Eastern Sicily), despite of protected status, represents an area in which data on benthic assemblages are lacking. In fact, although in the past times some inventories of species were published for algae (Cavaliere, 1963), sponges (Labate & Arena, 1964), echinoderms (Cavaliere, 1971), and molluscs

(Spada, 1969; Parenzan, 1979), data about benthic communities are still poorly documented. The molluscs, which include at least one exclusive endemic species and some peculiar eco-morphotypes (Priolo, 1965; Parenzan, 1979), were also employed as models of environmental complexity of Italian brackish and marine habitats (Iannotta et al., 2009). More recently, the anthropogenic introduction of molluscs in the Faro Lake was highlighted by Cosentino et al. (2009), but the consequent impact on the indigenous benthic assemblages was not still investigated.

Aim of the present paper is to provide a first contribution to the knowledge of the actual soft-bottom mollusc community in the Faro Lake; to describe their variations on a decadal scale, based on unpublished data sets; to individuate a possible biodiversity loss due to anthropogenic impacts.

MATERIALS AND METHODS

Study area

The Faro Lake (Fig. 1), although characterized by reduced dimension (0.263 Km²), represents the deepest coastal basin in Italy, reaching a maximum depth of 29 m in the funnel-shaped eastern part. By contrast, the shallower western side does not exceed 3 m depth. It receives marine waters from the nearby Strait of Messina, through a narrow and shallow channel, which extends for almost 1 km in length. During the summer period, a transient connection with the Tyrrhenian Sea is artificially realized by a further channel that normally is silted up. The lake is characterized by a meromictic regime, with anoxic and sulphidic waters that generally are confined below 15 m depth. The surface waters are mesotrophic, with a predominant heterotrophic biomass in the particulate matter (Leonardi et al., 2009) and regular blooms of photosynthetic bacteria just below the oxycline (Saccà et al., 2008). The thermo-haline stratification is not stable, and the poorly oxygenated waters can spread towards the surface in autumn (Sorokin & Donato, 1975). Exceptional seawater inflows origine strong alterations of the anoxic layer and temporary diseases of all aerobic organisms (Giuffrè & Pezzani, 2005).

The lake was historically submitted to various human activities, that repeatedly modified the basin



Figure 1. Upper pane: The Capo Peloro area, between the Tyrrhenian Sea and the Strait of Messina. The Faro lake is indicated. Lower pane: Sampling station location.

morphology along the last ten centuries (Mangano et al., 2011). At the present time, the shallower beds are affected by traditional practices of clam culture, whilst the deeper zone is affected by organic and carbonate inputs by mussel farming. The anthropogenic pressure, due to the extensive landscape urbanization, is also responsible of a moderate chemical and biological contamination (Licata et al., 2004; Sorgi et al., 2006).

Data sets

Soft bottom samples were collected in the Faro Lake during spring and autumn 1991, and spring 1993, 2006, 2010, in the framework of local "PRA" and national "PRIN" programs. Since the respective sampling plans partially overlapped, six recurrent stations were selected in the shallower area (1-2.5 m depth) to obtain temporal replicates; the station 3 was excluded since affected by clam-culture activities (Fig. 1). Samples were carried out by means of a 5 dm³ Van Veen grab (three random replicates inside 10x10 m stations), washed on field by means of 1 mm mesh sieves, and stored in 70% ethanol. Mollusc fauna was determined at the species level, and the abundances were submitted to univariate (not transformed data) and multivariate (square root transformed data) statistical analysis, by means of PRIMER 6.1 package.

In addition, the present distribution of both detected endemic and introduced taxa, was checked by direct SCUBA observations during spring-summer 2010, from 0.5 to 10 m depth.

RESULTS

The selected data set, reviewed in accordance with WoRMS (<http://marinespecies.org/>), accounted a total of 46 mollusc species, most of which were gastropods (30 species). Bivalves accounted 15 species, whilst polyplacophorans were represented by only one species. Fourteen gastropods and eight bivalves, previously cited by Parenzan (1979), were not recorded, whilst nine gastropods, eight bivalves and one polyplacophoran were added (Table 1). Such discrepancy did not prove a priori that substantial changes occurred in the mollusc assemblage composition, since the two inventories reflected different sampling method and effort. Furthermore,

species as *Haminoea ortei* Talavera, Murillo et Templado, 1987, and *Mancikellia parrussetensis* (Giribet et Peñas, 1999), were described afterwards the Parenzan note. Differently, recent settlement of the non-native *Cerithium scabridum* Philippi, 1848, *Crassostrea gigas* (Thunberg, 1793), and *Anadara transversa* (Say, 1822), might be in accordance to the introduction and spreading of these species in the Mediterranean Sea (e.g. Streftaris & Zenetos, 2006; Crocetta et al., 2009). The present data set also confirmed the occurrence of the exclusive endemic *Nassarius tinei* (Maravigna in Guérin, 1840), *Jujubinus striatus delpreteanus* Sullioti, 1889, and *Gibbula adansoni sulliotti* Monterosato, 1888, both reported in the most recent check-list of Italian probobranchs (Oliverio, 2008). The peculiar eco-morphotype *Polititapes aureus* var. *laeta* (Poli, 1791), reported in old literature data (Aradas & Benoit, 1870), was frequently recorded.

The 46 species identified in the 1991-2010 data set were differently distributed in time and space, and only a minor number of them was found in all the examined samples. The total number of species per sample, S (Fig. 2), that ranged from one in 2006 to fifteen in 2010, showed a clear decreasing trend from 1991 to 2006, followed by a remarkable increase in 2010. In this latter year, the highest minimum, maximum and average S values were recorded. In general, the spread between minimum and maximum values was weak for each year, except for the 1991, that accounted for the second highest and the second lowest S in the whole data set. Such trend was in accordance with Margalef richness, d (Fig. 2). Similarly, the Shannon diversity, H' (Fig. 2), showed a marked decrease from 1991 (highest maximum value) to 2006, and a following increase. In 1991 the widest spread between the maximum and the minimum value was observed, while the narrowest range was found in 2010. The Pielou's index, J' (Fig. 2), further put in evidence the 2006 peculiarity, whose very poor assemblages ranged from a totally uneven condition to the highest evenness.

In general, the different levels of organization found inside each annual group of samples were overcome by the inter-annual changes that affected the soft bottom assemblages. Such preponderance of the inter-annual variability with respect to the spatial patchiness was also confirmed by the Bray-Curtis similarity index and related cluster analysis

CHECK-LIST	1979	1991-2010
POLIPLACOPHORA		
<i>Acanthochitona crinita</i> (Pennant, 1777)		X
GASTROPODA		
<i>Alvania cimex</i> (Linnaeus, 1758)		X
<i>Alvania discors</i> (Allan, 1818)	X	
<i>Alvania geryonia</i> (Nardo, 1847)	X	X
<i>Alvania lanciae</i> (Calcara, 1845)	X	X
<i>Bittium latreillii</i> (Payraudeau, 1826)		X
<i>Bittium reticulatum</i> (da Costa, 1778)	X	X
<i>Caecum auriculatum</i> de Folin, 1868	X	
<i>Calliostoma</i> sp.	X	
<i>Cerithium renovatum</i> Monterosato, 1884	X	X
<i>Cerithium scabridum</i> Philippi, 1848		X
<i>Cerithium vulgatum</i> Bruguière, 1792	X	X
<i>Clanculus jussieui</i> (Payraudeau, 1826)	X	
<i>Conus ventricosus</i> Gmelin, 1791	X	X
<i>Cyclope neritea</i> (Linnaeus, 1758)	X	X
<i>Dikoleps nitens</i> (Philippi, 1844)		X
<i>Eatonina ochroleuca</i> (Brusina, 1869)		X
<i>Ecrobia ventrosa</i> (Montagu, 1803)	X	
<i>Euspira intricata</i> (Donovan, 1804)	X	
<i>Euthria cornea</i> (Linnaeus, 1758)	X	
<i>Fissurella nubecula</i> (Linnaeus, 1758)	X	
<i>Gibberula miliaria</i> (Linnaeus, 1758)	X	X
<i>Gibbula adansoni sulliotti</i> Monter., 1888	X	X
<i>Gibbula turbinoides</i> (Deshayes, 1835)	X	X
<i>Haminoea hydatis</i> (Linnaeus, 1758)	X	X
<i>Nassarius corniculum</i> (Olivi, 1792)	X	X
<i>Nassarius mutabilis</i> (Linnaeus, 1758)	X	X
<i>Nassarius tinei</i> (Maravigna, 1840)	X	X
<i>Odostomia scalaris</i> MacGillivray, 1843	X	
<i>Peringia ulvae</i> (Pennant, 1777)		X
<i>Phorcus articulatus</i> (Lamarck, 1822)	X	X
<i>Phorcus mutabilis</i> (Philippi, 1846)	X	X

CHECK-LIST	1979	1991-2010
<i>Pisania striata</i> (Gmelin, 1791)	X	X
<i>Pisinna glabrata</i> (Von Mühlfeldt, 1824)		X
<i>Potamides conicus</i> (Blainville, 1829)	X	
<i>Pusillina lineolata</i> (Michaud, 1832)	X	X
<i>Skeneopsis planorbis</i> (Fabricius O., 1780)	X	
<i>Thylacodes arenarius</i> (Linnaeus, 1758)	X	
<i>Tricolia pullus</i> (Linnaeus, 1758)	X	
BIVALVIA		
<i>Abra alba</i> (W. Wood, 1802)	X	
<i>Abra prismatica</i> (Montagu, 1808)	X	
<i>Abra segmentum</i> (Récluz, 1843)	X	X
<i>Abra tenuis</i> (Montagu, 1803)	X	
<i>Anadara transversa</i> (Say, 1822)		X
<i>Cerastoderma glaucum</i> (Bruguière, 1789)		X
<i>Chamelea gallina</i> (Linnaeus, 1758)		X
<i>Corbula gibba</i> (Olivi, 1792)	X	X
<i>Crassostrea gigas</i> (Thunberg, 1793)		X
<i>Gastrana fragilis</i> (Linnaeus, 1758)		X
<i>Gibbomodiola adriatica</i> (Lamarck, 1819)	X	
<i>Gouldia minima</i> (Montagu, 1803)	X	
<i>Loripes lucinalis</i> (Lamarck, 1818)	X	X
<i>Mancikellia parrussetensis</i> (G.&Peñ.,1999)		X
<i>Modiolus barbatus</i> (Linnaeus, 1758)		X
<i>Mytilaster minimus</i> (Poli, 1795)		X
<i>Mytilus galloprovincialis</i> Lamarck, 1819	X	X
<i>Ostrea stentina</i> Payraudeau, 1826	X	
<i>Papillicardium papillosum</i> (Poli, 1791)	X	
<i>Parvicardium exiguum</i> (Gmelin, 1791)	X	X
<i>Polititapes aureus</i> var. <i>laeta</i> (Poli, 1791)	X	X
<i>Teredo</i> sp.	X	
<i>Venerupis decussata</i> (Linnaeus, 1758)	X	X

Table 1. Comparison from the Parenzan (1979) check-list and the present data.

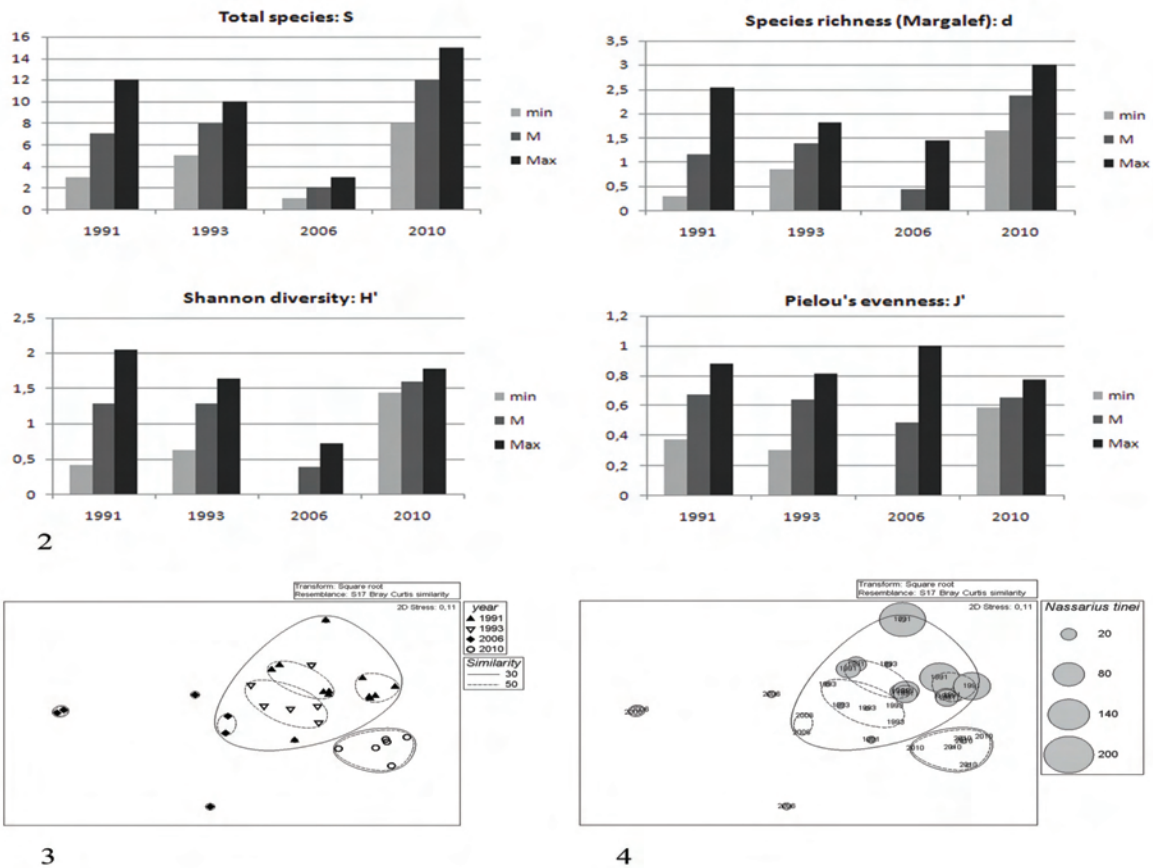


Figure 2. Minimum (min), maximum (Max) and average (M) values found in the four sampling years, for total number of species for sample, S; Margalef richness, d; Shannon diversity, H' ; and Pielou's evenness, J' .

Figures 3, 4. 2D MDS ordination for the benthic assemblages (Fig. 3), and bubble plot for the species *Nassarius tinei* (Fig. 4).

and 2D MDS ordination, which showed the samples grouped mainly in accordance with the sampling year (Fig. 3). Similarity grouped the whole 1991, 1993 and some 2006 samples, at 50%, whilst the 2010 grouped apart. At 30% similarity level, the 1993 almost entirely clustered, differently from the 1991 seasonal data set, that showed two main sub-clusters and two single samples, not correlated with the sampling seasons.

The hypothesis of a temporal shift that affected a lowly diversified benthic assemblage was verified by means of one-way and two-way ANOSIM tests (factors: year, depth, and station), which confirmed the discriminating role played by the factor "year" alone (Global R: 0.638; p: 0.1%; number of permuted statistics greater than or equal to Global R: 0). The Simper test applied to the groups "year" showed intra-group similarities ranging from a minimum of

21%, in 2006, to a maximum of 61%, in 2010. The 1991 group (Average similarity: 50.74%) was mainly characterized by the endemic gastropods *N. tinei* (33.98% contribution) and *G. adansoni sulliotti* (21.5%), with further 21.06% was due to the local eco-phenotype *P. aurea* var. *laeta*. The 93.46% similarity was reached with the contribution of five species in total. In the 1993 group (Average similarity: 50.92%), the 73.29% of cumulative intra-group similarity was due to the bivalves *P. aurea* var. *laeta*, *L. lucinalis* and *Venerupis decussata* (Linnaeus, 1758), whilst a minor contribution (8.59%) was done by *G. a. sulliotti*. Three species of bivalves: *Loripes lucinalis* (Lamarck, 1818), *Corbula gibba* (Olivi, 1792) and *Polititapes aureus* var. *laeta* (Poli, 1781), accounted 100% of the 2006 internal similarity, whilst in 2010 three gastropod species: *Gibbula adansoni sulliotti* Monterosato,

1888, *Haminoea navicula* (da Costa, 1778) and *Hexaplex trunculus* (Linnaeus, 1758), were responsible of the 69% intra-group similarity, which reached 91% with the contribution of further four species.

The Simper test also indicated a high inter-group dissimilarity, reaching a maximum of 95% in the 2006 vs. 2010 comparison. Such extreme difference between the 2006 and 2010 assemblages was essentially due to 13 species (90% total dissimilarity), with a major contribution of *G. adansoni sulliotti* (18.53%). This endemic taxa was the second major responsible of intergroup dissimilarity (19.47%) in the 1991 vs. 2006 (total average dissimilarity: 89.35), whilst *N. tinei* (20.35%) and *P. aureus* var. *laeta* (18.57%), provided the first and third contributions, respectively. Similarly, in 1993 vs. 2006 (total average dissimilarity: 81.54%), *G. a. sulliotti* contributed for 15.15%, following to *P. a. var. laeta* (22.53%) and preceding *V. decussata* (13.11%). Such marked dissimilarity of both 1991 and 1993 groups in respect to 2006, weakly declined in respect to 2010 (69.93% and 74.24%, respectively). The greater contribution to the 1991 vs. 2010 dissimilarity was done by *P. a. var. laeta* (15.54%), *N. tinei* (14.48%) and *H. navicula* (10.79%), whilst *P. a. var. laeta* (15.75%), *G. a. sulliotti* (11.56%) and *H. navicula* (11.51%) were the most responsible of the 1993 vs. 2010 dissimilarity. The lowest dissimilarity, found between the 1991 and 1993 assemblages (62.90%), was especially due to the endemic taxa *P. a. var. laeta* (17.42%), *G. a. sulliotti* (16.43%) and *N. tinei* (16%). The differentiate time-distribution of the endemic *N. tinei* in comparison with the sampling clustering is shown in Figure 4.

Both intra-group similarity and inter-group dissimilarity testified of remarkable changes that occurred in the soft-bottom mollusc assemblages since 1991, as also testified by the main univariate indexes of community structure. Changes fundamentally affected the whole soft-bottom assemblage, whose spatial variability in 1991, 1993 and 2010 was low in respect to the temporal changes. The mollusc assemblages found in 2006, characterized by poor faunal composition and structure further than by high spatial heterogeneity, were notably different from those recorded in the precedent and successive times.

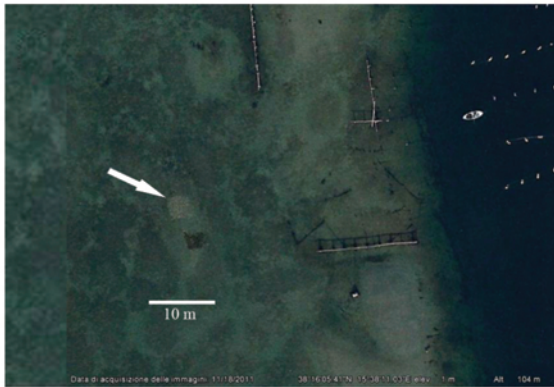
In general, the investigated assemblages accounted a low number of species, as characteristic of estuarine soft-bottom communities, three to six of which were responsible of the 90% intra-group si-

milarity. Such characterizing species included some endemic taxa, whose contribution to the assemblage composition notably declined in time, since 1991 (three endemic taxa responsible of 76% internal similarity), up to 1993 (two species, 45% similarity) and 2006 (one species, 25% similarity). The benthic recovery following the 2006 decline was marked by the prevalent role of the endemic *G. a. sulliotti* (30.90%) together with a very low contribution by *P. aureus* var. *laeta* (2.70%). Notably, the sole endemism that was recognized at the species level, *N. tinei*, had a primary role in 1991 alone, whilst did not significantly contribute to the intra-group similarity afterwards. Furthermore, the sole endemism that was recurrent in the whole time-series, *P. aureus* var. *laeta*, did not represent a true taxonomic entity, but only a local eco-morphotype that is suspected to occur in other Mediterranean environments. A further endemic subspecies, *J. striatus delpreteanus*, occurred only once, in 2010. The endemisms which loosed their prominent role in the intra-group similarity were recognized as minor components in the inter-group dissimilarity, together with the non-native species, *Cerithium scabridum*, *Crassostrea gigas* and *Anadara transversa*. Such low occurrence of non-native species that are known for their invasiveness (Streftaris & Zenetos, 2006) apparently contrasted with their regular introduction in the Faro Lake by means of mollusc trade. The extensive survey carried out after the 2010 sampling showed artificial bed of the non-native oyster, *Crassostrea gigas*, (Figs. 5, 6) together with the Manila clam, *Venerupis philippinarum* (A. Adams et Reeve, 1850) (Fig. 7). The progressive naturalization of *C. gigas* since 2010 was proved by records of juveniles and small sized adults in the sampling stations and surrounding lake-floor. *V. philippinarum*, despite a more than decadal farming practice, did not naturally recruit in the lake, differently from *A. transversa*, which was accidentally introduced with the Manila clam commercial stocks. For a contrast, the *C. scabridum* settlement might be due to secondary natural dispersion from South-Eastern Sicily (Barash & Danin, 1977).

The survey which allowed to individuate sources of anthropogenic bio-pollution (Olenin et al., 2007) also proved that declining endemic taxa were locally concentrated in some "refuge sites", that not necessarily represented undisturbed areas. In particular, *J. s. delpreteanus* colonized residual sea-grass

meadows of *Cymodocea nodosa* (Ucria) Ascherson, 1870; whilst *N. tinei* and *G. a. sulliotti* were frequently recorded as opportunistic necrophagous in the commercial clam-beds (Figs. 8, 9), due to the high prey concentration and mortality rate. By con-

trast, other endemisms and pseudo-endemisms known from old literature data, as the eco-morphotypes *Conus ventricosus* var. *ater* Philippi, 1836, whose decline was documented since Parenzan (1979), and *Potamides conicus* var. *peloritana*



5



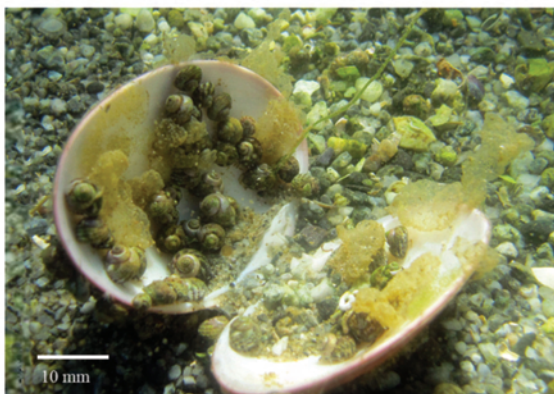
6



7



8



9



10

Figure 5. Aerial view of the Faro Lake (by Google earth); the arrow indicates a commercial oyster bed. Figure 6. The same oyster bed photographed in situ. Figure 7. Underwater view of a commercial Manila clam bed and (Figure 8) view of *Nasarius tinei* in the same clam bed. Figure 9. Underwater view of *Gibbula adansoni sulliotti* feeding upon a dead *Callista chione* (Linnaeus, 1758) commercial clam. Figure 10. Samples of dead *Gari depressa* from the Faro Lake beds.

(Cantraine, 1835), might be totally extinct. Similarly, some autochthonous species as *Gari depressa* (Pennant, 1777), which were commercially exploited in past times (Philippi, 1836), actually can be recorded as death assemblage only (Fig. 10).

DISCUSSIONS AND CONCLUSIONS

The comparison of four data-sets collected in the Faro Lake during the latter two decades showed a notable transformation of the soft-bottom mollusc assemblages. Such transformation affected both composition and structure of the mollusc taxocoenosis, involving biodiversity changes. Basic indices of community structure (S, d, H', J') showed a decline that was particularly marked in the 2006, before a recover in 2010. On a wider temporal scale, some evidences exists that native mollusc populations, known as local eco-morphotypes, were extinct or strongly reduced in the last century. Lacking the proves that human activities caused such an abrupt and generalized decline, the 2006 benthic depletion might be explained as a transient effect of diseases due to anoxic layer alterations (Giuffrè & Pezzani, 2005), also facilitated by intensive mussel farming and related organic sedimentation increase.

The benthic re-colonization, that involved side supply processes from the nearby coastal areas, provided stenohaline and moderately euryhaline species of marine origin, whilst euryvalent taxa spread from the connected Ganzirri Lake. Nevertheless, such latter reservoir of local biodiversity is lacking of the major endemic taxa, as *N. tinei* and *J. striatus delpreteanus*, whose surviving is tied to limited "refuge sites" inside the same Faro basin. On the regional scale, habitat fragmentation prevents genic fluxes from other Sicilian TWs, but allochthonous taxa are daily introduced by mussel trade from remote source. Since local sources of biodiversity and non-native taxa introduction support re-colonization by means of unpredictable recruitments, the 2010 biodiversity recovery produced an increased number of species, but a less structured living assemblage with respect to the 1991 mollusc taxocoenosis. The introduced species did not show their potential invasiveness so far, representing a smaller part of the 2010 assemblage, and a direct link between their settlement in the Faro Lake and loss of the endemic taxa was not proved. Nevertheless, the

mollusc farming, which is widely responsible of introduction in Western Mediterranean (Galil, 2008), severely impacts both on the habitat structure and dynamics at the water-sediment interface, thus favouring the opportunistic taxa. Other anthropogenic impacts, as chemical/organic pollution, that also affects the Faro Lake ecosystem, are less recognizable in their effects. The anthropogenic-induced decline of the well adapted endemisms, altering the community structure, negatively affects the multiple species relationships, thus reducing the effectiveness of the "priority effect" to contrast biological invasions (Case, 1990).

Concomitant bio-pollution and native species decline are linked aspects of a "biotic homogenization" that notably affects worldwide biogeography (Olden, 2006), and involves under-evaluated effects on the present ecosystem functioning. Although the measures of mollusc diversity in the Faro Lake did not show dramatic changes in the last decades, strong signals of biodiversity reduction were detected. The high number of menaced endemic taxa and ecological adaptations, make the mollusc assemblages in the Faro Lake a case-study for the effect of species introduction in confined environments.

ACKNOWLEDGEMENTS

This research has been supported by the Messina University, and sponsored by the "Provincia-Regionale di Messina" the management official body of the reserve. Facilities have been provided by the mussel farms FARAU s.r.l. and SACOM s.r.l. A relevant contribution was also provided concerning field and in laboratory by the researchers A. Cosentino and M.C. Mangano, and by the students A. Rindone, S. Giccione, S. De Matteo, A. Spinelli, M. Cintorino and M. Cavallaro.

REFERENCES

- Airoldi L. & Beck M.W., 2007. Loss, status and trends for coastal marine habitats of Europe. *Oceanography and Marine Biology: An Annual Review*, 45: 345-405.
- Aradas A. & Benoit L., 1870. *Conchigliologia vivente marina della Sicilia e delle isole che la circondano. Atti dell'Accademia Gioenia di Scienze Naturali, Catania, ser. III, 6:1-324. 5 tavv.*

- Barash A.I. & Danin Z., 1977. Additions to the knowledge of Indo-Pacific mollusca in the Mediterranean. *Conchiglie*, 13: 85-116.
- Basset A., Sabetta L., Fomesu A., Mouillot D., Do Chi T., Viaroli P., Giordani G., Reizopoulou S., Abbiati M. & Carrada G.C., 2006. Typology in Mediterranean transitional waters: new challenges and perspectives. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 16: 441-455.
- Borja A., Franco J. & Pérez V., 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin*, 40: 1100-1114.
- Case T.J., 1990. Invasion resistance arises in strongly interacting species-rich model competition communities. *Proceedings of National Academy of Sciences of the United States of America*, 87: 9610-9614.
- Cavaliere A., 1963. *Biologia ed ecologia della flora dei laghi di Ganzirri e Faro, sua sistematica e distribuzione stagionale*. *Bollettino Pesca, Piscicoltura e Idrobiologia*, 18: 171-186.
- Cavaliere A., 1971. *Fauna e flora dei laghi di Faro e Ganzirri. 3 - Osservazioni bio-ecologiche sugli echinodermi del lago di Faro (Messina)*. *Bollettino Pesca, Piscicoltura e Idrobiologia*, 26: 237-242.
- Cosentino A., Giacobbe S. & Potoschi A., 2009. The CSI of the Faro lake (Messina): a natural observatory for the incoming of marine alien species. *Biologia Marina Mediterranea*, 16: 132-133.
- Crocetta F., Renda W. & Colamonaco G., 2009. New distributional and ecological data of some marine alien molluscs along the southern Italian coasts. *Marine Biodiversity Records*, 2, e23: 1-7.
- De Wit R., 2007. Biodiversity and ecosystem functioning in transitional waters; the point of view of a microbial ecologist. *Transitional Waters Bulletin*, 1: 3-16.
- Evangelopoulos A., Spyros E. & Koutsoubas D., 2009. Phytoplankton and macrofauna in the low salinity ponds of a productive solar saltworks: spatial variability of community structure and its major abiotic determinants. *Global NEST Journal*, 11: 64-72.
- Galil B., 2008. Alien species in the Mediterranean Sea - which, when, where, why? *Hydrobiologia*, 606: 105-116.
- Giuffrè G. & Pezzani R., 2005. Annual nano-microphytoplankton succession in the meromictic brackish Lake Faro (Messina - Sicily) in relation to physical-chemical conditions. *Il Naturalista Siciliano*, 29: 153-168.
- Knottnerus O.S., 2005. History of human settlement, cultural change and interference with the marine environment. *Helgoland Marine Research*, 59: 2-8.
- Iannotta M.A., Toscano F. & Patti F.P., 2009. *Nassarius corniculatus* (Olivi, 1792) (Caenogastropoda: Nassariidae): a model of environmental complexity of Italian brackish and marine habitats. *Marine Ecology*, 30: 106-115.
- Labate M. & Arena P., 1964. La fauna dei poriferi nei laghi di Ganzirri e Faro. *Archivi di Zoologia Italiani*, 49: 249-280.
- Leonardi M. & Giacobbe S., 2001. The Oliveri-Tindari lagoon (Messina-Italy): Evolution of the trophic-sedimentary environment and mollusc communities in the last twenty years. In: *Mediterranean Ecosystem: Structure and Processes*. F.M. Faranda, L. Guglielmo & G. Spezie (eds.). Springer-Verlag Italia: 305-310.
- Licata P., Trombetta D., Cristani M., Mertino D. & Naccari F., 2004. Organochlorine compounds and heavy metals in the soft tissue of the mussel *Mytilus galloprovincialis* collected from Lake Faro (Sicily, Italy): *Environment International*, 30: 805-810.
- Leonardi M., Azzaro F., Azzaro M., Caruso G., Mancuso M., Monticelli L.S., Maimone G., La Ferla R., Raffa F. & Zaccone R., 2009. A multidisciplinary study of the Capo Peloro brackish area (Messina: Italy): characterization of trophic condition, microbial abundances and activities. *Marine Ecology*, 30 (suppl.1): 33-42.
- Levin L.A., Boesch D.F., Covich A., Dahm C., Erséus C., Ewel K.C., Kneib R.T., Moldenke A., Palmer M.A. & Snelgrove P., 2001. The function of marine critical transition zones and the importance of sediment biodiversity. *Ecosystems*, 4: 430-451.
- Lotze H.K., Lenihan H.S., Bourque B.J., Bradbury R.H., Cooke R.G., Kay M.C., Kidwell S.M., Kirby M.X., Peterson C.H. & Jackson J.B.C., 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science*, 312 (5781): 1806-1809
- Manganaro A., Pulicanò G. & Sanfilippo M., 2011. Temporal evolution of the area of Capo Peloro (Sicily, Italy) from pristine site into urbanized area. *Transitional Waters Bulletin*, 5: 23-31.
- Mazzola A., Bergamasco A., Calvo S., Caruso G., Chermello R., Colombo F., Giaccone G., Gianguzza P., Guglielmo L., Leonardi M., Riggio S., Sarà G., Signa G., Tomasello A. & Vizzini S., 2010. Sicilian transitional waters: current status and future development. *Chemistry and Ecology*, 26: 267-283.
- Munari C. & Mistri M., 2010. Towards the application of the Water Framework Directive in Italy: Assessing the potential of benthic tools in Adriatic coastal transitional ecosystems. *Marine Pollution Bulletin*, 60: 1040-1050.
- Olden J.D., 2006. Biotic homogenization: a new research agenda for conservation biogeography. *Journal of Biogeography*, 33: 2027-2039.

- Olenin S., Minchin D. & Daunys D., 2007. Assessment of biopollution in aquatic ecosystems. *Marine Pollution Bulletin*, 55: 379-394.
- Oliverio M., 2008. Gastropoda Prosobranchia. *Biologia Marina Mediterranea*, 5 (suppl.): 235-278.
- Parenzan P., 1979. Fauna malacologica dei laghi di Ganzirri e del Faro (Messina). *Thalassia Salentina*, 9: 67-78.
- Philippi R.A., 1836. *Enumeratio molluscorum Siciliae cum viventium tum in tellure tertiaria fossili quom quae in itinere suo observavit. Sumptibus Simonis Schroppii et sociorum, Berolini*, 1-267. 12 tavv.
- Ponti M., Pinna M., Basset A., Moncheva S., Trayanova A. & Georgescu L.P., 2008. Quality assessment of Mediterranean and Black Sea transitional waters: comparing responses of benthic biotic indices. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18 (S1): 62-75.
- Priolo O., 1965. Nuova revisione delle conchiglie marine di Sicilia. *Atti Accademia Gioenia di Scienze Naturali, Catania, Memorie* 16: 75-118.
- Saccà A., Guglielmo L. & Bruni V., 2008. Vertical and temporal microbial community patterns in a meromictic coastal lake influenced by the Straits of Messina upwelling system. *Hydrobiologia*, 600: 89-104.
- Sorokin J.I. & Donato N., 1975. On the carbon and sulphur metabolism in the meromictic Lake Faro (Sicily). *Hydrobiologia*, 47: 241-252.
- Sorgi C., Cavallaro M., Brianti E., Ferlazzo M. & Giannetto S., 2006. *Cryptosporidium* and *Giardia* in mussels (*Mytilus galloprovincialis*) from Faro salt-lake, Sicily. *Parassitologia*, 48: 296.
- Spada A., 1969. Breve esplorazione malacologica del lago di Ganzirri e del Pantano di Torre del Faro presso Messina. *Conchiglie, Milano*, 5: 60-65.
- Streftaris N. & Zenetos A., 2006. Alien marine species in the Mediterranean - the 100 'worst invasive' and their impact. *Mediterranean Marine Science*, 71: 87-118.
- Wolff W.J., 1998. Exotic invaders of the meso-oligohaline zone of estuaries in the Netherlands: why are there so many? *Helgoland Marine Research*, 52: 393-400.