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RESEARCH ARTICLE

The macrozoobenthic community of the Santa Gilla lagoon (Southern Sardinia, Italy)

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Abstract

1 - Macrozoobenthos is one of the most significant communities of hydrobionts for assessing the ecological state of a water body. In spite of its importance, only few data concerning the macrobenthic community of Santa Gilla lagoon are available;

2 - Santa Gilla is one of the most important wetlands in Sardinia. The aim of this study is to give data on species composition of its macrozoobenthic community;

3 - Sampling has been carried out in 2010-2011 in July, October, January and April, in three stations located along a salinity gradient and the main environmental parameters were measured;

4 - A total of 13031 specimens belonging to 92 taxonomic groups and 5 main phyla (Anellida, Mollusca, Arthropoda, Cnidaria and Nemertea) were found. Among them, 52 different taxa were collected and pointed out for the first time in Santa Gilla lagoon in this work.

5 - Finally, seasonal and space differences were observed in the abundance values of the main taxonomic groups and in the diversity indices values.

Keywords: Zoobenthos, Brackish water environment, Santa Gilla lagoon, biodiversity.

Introduction

Coastal lagoons are singular ecosystems, ecotones among freshwater, marine and terrestrial biotopes, and thus their biotic structure, including macrozoobenthic assemblage, depends on these component equilibrium. They are also characterized by wide and rapid changes in environmental parameters, such as salinity, dissolved oxygen and temperature (Basset *et al.*, 2006). In addition, the biotic structure of coastal inlet, as habitat islands along the coastal landscape, are conditioned by immigration and emigration processes as well as habitat selectivity (Zobel, 1997).

Soft bottom benthos of coastal waters, indeed, is subjected to different sources of disturbance, both from natural and human origin (Occhipinti-Ambrogi *et al.*, 2005). In particular, transitional water such as coastal lagoons, due to their location between sea and land, often result to be deeply influenced by large amounts of organic and mineral nutrients derived from urban, agricultural, and industrial effluents. Consequently, benthic assemblages respond to environmental stress modifying their structure (e.g. number of species, abundance, biomass, trophic structure) and derived indices (e.g. diversity indices). The resultant benthic macrofauna community plays important roles in ecosystem processes of nutrient cycling, pollutant metabolism, dispersion and burial, etc. (Snelgrove, 1998). For these reasons and for its great responsiveness to different factors, macrozoobenthos is one of the most significant communities of hydrobionts for assessing the ecological state of a waterbody and it is widely used as indicators of habitat condition in marine and estuarine environments (Bilyard, 1987 and Gibson *et al.*, 2000). Its knowledge is a prerequisite for evaluating ecosystems and for selecting sustainable policies of ecosystem management (Ludovisi *et al.*, 2013).

The study on the macrozoobenthos of the Santa Gilla lagoon (Cagliari, south Sardinia) is scanty and the knowledge is limited, given that only a few and incomplete data are available. Indeed, the preview studies were carried out basically on Crustacea (Porcu *et al.*, 1983), Polychaeta (Carrada, 1986) or result in any case preceding the restoration plan as the investigations conducted by Cottiglia in the 70s (Cottiglia *et al.*, 1973). Many groups remain still unstudied. Considering that recent and complete data are missing, the aim of this study is to give data on species composition of the macrozoobenthic community related to seasonal variations and distribution in the Santa Gilla lagoon.

Material and Methods

Study area

The Santa Gilla lagoon is one of the most important wetlands in Sardinia, being classified as a Special Protection Area (Directive 79/409 CEE), wetland site of international importance under the Ramsar Convention (D.M. 03/09/1980) since 1976 and Site of Community Importance (Directive 92/43 CEE).

The lagoon covers an area of about 1300 ha and it is located along the Southern coast of Sardinia (Fig. 1). In the south, the lagoon

Figure 1. Santa Gilla lagoon with the sampling stations.

opens onto the sea through a channel, while in the north it receives two freshwater inflows from the Flumini Mannu and Cixerri rivers. The average depth is 1 m (maximum depth 2 m in the artificial channel). The sediment is mainly sandy-silt (Degetto *et al.*, 1997; Frontalini *et al.*, 2009).

Santa Gilla lagoon has been scene of several environmental changes in the last decades, as its extension, the implementation of the salt works by Contivecchi, the establishment of the large industrial complex of Macchiareddu-Grogastu (Frontalini *et al.*, 2009) and the construction of the industrial port "Porto Canale". Indeed, starting from about 1925, the plan area of the active lagoon was gradually reduced from about 4000 ha to the present value of about 1300 ha (Atzeni *et al.*, 1998). In addition, the construction of a commercial port and the enlargement of the runways at the Elmas airport reduced the water-exchange rate of the lagoon (Defendi, 1995).

Moreover, the lagoon has been characterized by a chemical and organic pollution for several decades, due to the industrial discharges of Hg, Pb and Zn compounds and municipal untreated sewage.

In 1986, a restoration plan took place and the heavy metals contained in the lagoon were removed by dredging of the bottom, while their inflow has been gradually decreasing and has presently ceased (Atzeni *et al.*, 1998). Unremoved pollutants could still exist and are bound to influence the benthic communities.

Prior to these changes, on the whole, the typical macrobenthos biocenosis consisted on lamellibranches such as *Ruditapes decussatus*, *Scrobicularia plana*, *Abra ovata* and *Cerastoderma glaucum*, amphipods such as *Gammarus aequicauda* and *Corophium volutator* and isopods such as *Sphaeroma hoockeri*, *Idothea* sp. and *Cyathura* sp. (Cottiglia, 1973).

As reported by Carrada, 1986, the most abundant taxon was the class of Polychaeta (74.4%) and the most abundant species resulted *Streblospio shrubsolii*, *Nereis diversicolor*, *Polydora ciliata*, *Prionospio malmgreni*, *Capitella capitata*, *Mediomastus filiformis*, *Spio filicornis* and *Desdemona ornata*. Likewise, as descripted by Porcu *et al.* (1983), the taxon of crustaceans resulted important and consisted basically on Isopoda such as *Sphaeroma hookeri*, *Sphaeroma serratus*, *Idothea chelipes* and *Cyathura carinata* and on Amphipoda such as *Gammarus insensibilis*, *Gammarus aequicauda*, *Melita palmata*, *Microdeutopus gryllotalpa*, *Stenothoe monoculoides*, *Erichtonius difformis*, *Caprella* sp., *Corophium insidiosum* and *Corophium orientale*.

Field and laboratory methods

Three stations, located along a salinity gradient, were investigated. Station 1 (S1) is the nearest to the sea, station 3 (S3) is the nearest to the freshwater sources, station 2 (S2) is intermediate. In each station, depth (cm) were measured and temperature (°C), salinity, conductivity (ms/cm), dissolved O_2 (mg/l; %sat) and pH of the water were recorded with a multiparametric probe (Hanna HI 9828).

Sampling has been carried out in July 2010, October 2010, January 2011 and April 2011. Three separated replicate sediment samples were taken with a Van Veen grab with a total surface of 0.18 m^2. Each sample was washed through a 1 mm mesh screen and narcotized with 7.5% magnesium sulfate. The material retained was fixed in 4% buffered formaldehyde and preserved in ethylic alcohol.

In the laboratory the macrofauna was sorted, identified to species level, at 7-40 x magnification by means of a stereomicroscope and, for the juvenile and small specimens, at 20-200 x magnification by using an optic microscope (Labrolux 12).

Differences in taxa distribution related with stations and seasons were tested by chi-square test. Plymouth Routines in Multivariate Ecological Research (PRIMER 6 beta) were used for diversity analysis. The number of individuals (N), the number of taxa (S) and the main diversity index as Shannon-Wiener diversity index (H′), Margalef richness index (d) and Pieulou'seveness index (J′) were calculated.

Results

Abiotic variables

The variationin water abiotic variables, in time and space, is shown in Table 1.

The water temperature showed the lowest value in January (11.4 °C) and the highest value in July (28.7 °C). Salinity and conductivity values at stations S1 and S2 decreased from July (34.6, 52.8 mS/cm; 33.4, 52.9 mS/cm, respectively) to January (25.0, 39.2 mS/cm; 21.3, 33.8 mS/cm, respectively) and increased in April (27.6, 37.1 mS/cm; 24.2, 33.2 mS/cm, respectively), while in station S3 salinity decreased from July (25.6, 43.0 mS/cm) to April (15.0, 19.4 mS/cm). Dissolved O_2 varied between the lowest value measured in October in Station S3 (4.9 mg l^{-1}; 57.8 % Sat), and the highest value in April in Station S2 (10.3 mg l^{-1}; 126.9 % Sat), while the values of pH ranged from 7.6 to 9.0.

Biotic variables

A total of 13031 specimens belonging to 92 taxonomic groups and 5 predominant phyla (Anellida, Mollusca, Arthropoda, Cnidaria and Nemertea) were collected. Anellida represented the most abundant taxon (61%), followed by Mollusca (29%), Arthropoda (8), Cnidaria (1%) and Nemertea (1%). Anellids resulted predominant in station S1 (74%) and S2 (71%), followed by Arthropoda (S1 = 12%; S2 = 10%) and Mollusca (S1 = 10%; S2 = 18%), while Mollusca (56%) dominated the community of station S3 where Anellida, in a ranking of importance, gained second place. The presence of Cnidaria and Nemertea was less important in all the stations, with low percentages values.

During the months sampled was possible to evidence differences in taxa composition: Anellida resulted the dominant phylum during July and April reaching high abundance values (80%; 74%), followed in July by Arthropoda (13%) and in April by Mollusca

Table 1 - Values of the water variables at different stations and months in Santa Gilla lagoon.

Station	Date	Depht (cm)	T (°C)	Salinity (psu)	Cond (mS/cm)	pH	OD (mg/l)	OD (%sat)
S1JUL	08/07/2010	84	25.2	34.6	52.8	8.1	6.6	94.7
S2JUL	08/07/2010	92.3	27.1	33.4	52.8	8.1	7.8	118.5
S3JUL	08/07/2010	53.0	28.7	25.6	43.0	8.2	8.5	124.1
SIOCT	19/10/2010	90.3	18.2	33.2	44.2	7.9	7.3	95.0
S2OCT	19/10/2010	79.0	16.2	28.6	37.0	7.8	7.1	86.9
S3OCT	19/10/2010	80.3	17.2	24.7	28.7	7.6	4.9	57.8
S1JAN	18/01/2011	79.3	12.5	25.0	39.2	8.3	8.0	87.5
S2JAN	18/01/2011	79.3	11.4	21.3	33.8	8.2	8.3	87.9
S3JAN	18/01/2011	101.0	11.8	21.8	33.4	9.0	8.3	87.9
S1APR	28/04/2011	92.0	17.7	27.6	37.1	7.9	9.0	111.0
S2APR	28/04/2011	126.0	18.3	24.2	33.2	8.0	10.3	126.9
S3APR	28/04/2011	106.0	18.4	15.0	19.4	7.8	7.2	80.8

(20%). Anellida became less important in the other two months analysed, reaching 43% in October and 37% in January (Fig. 2).
Among the anellids, the most representative class was Polychaeta and the most abundant species resulted *Streblospio shrubsolii* (48.3%), *Nereis diversicolor* (8.7%), *Boccardia polybranchia* (4.5%), *Cirriformia*

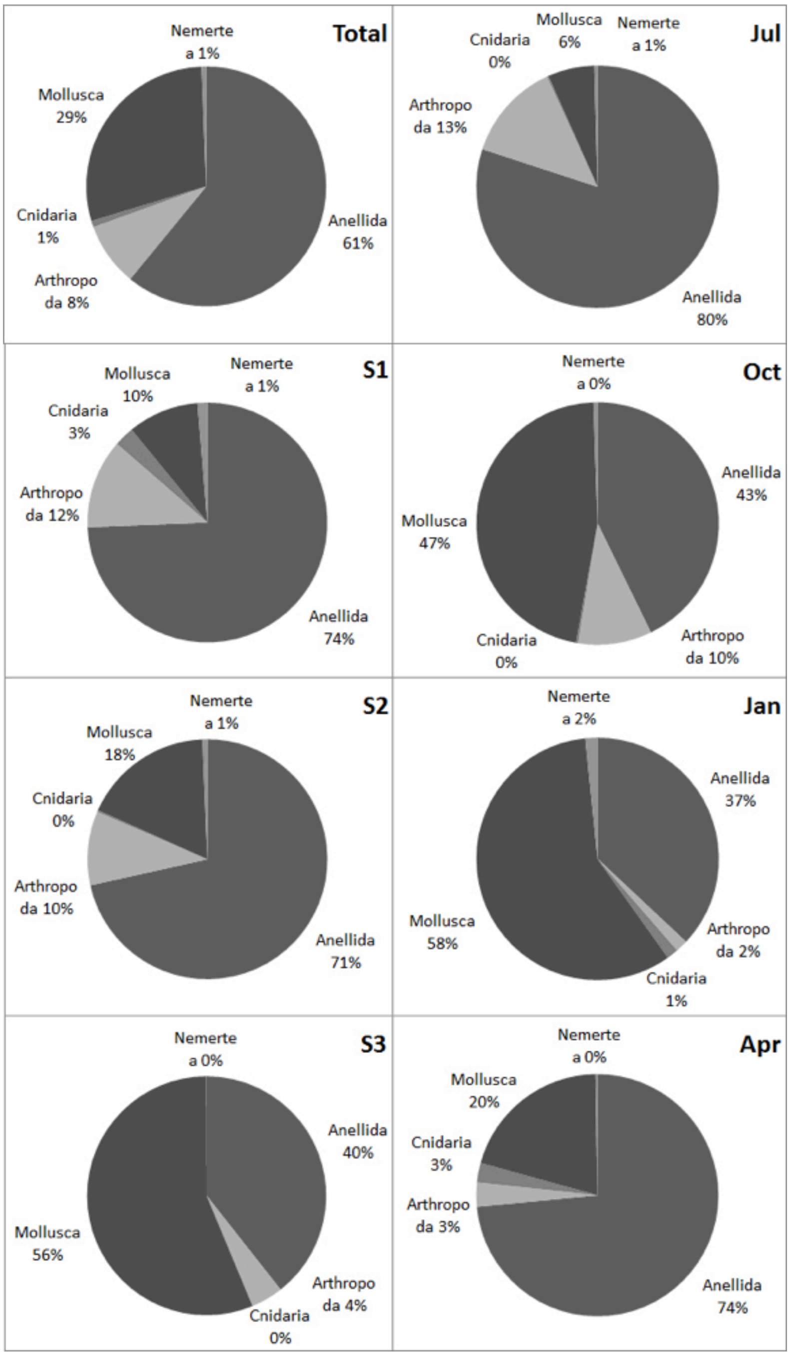

Figure 2. Distribution of the 5 most representative Phyla in the total sample, different months (Jul = July; Oct= October; Jan = January; Apr =April) and stations (S1 = Station 1; S2 = Station 2; S3 = Station 3) in the Santa Gilla lagoon.

tentaculata (4.2%), *Pseudopolydora antennata* (4.1%) and species belonging to the family Sabellidae (18.8%).

The phylum Mollusca resulted represented mostly by Bivalvia as *Arcuatula senhousia* (39.1%), *Abra alba* (38.1%), *Cerastoderma glaucum* (11.2%), *Ruditapes decussatus* (4.6%) and Gasteropoda of the genus Hydrobia (4.3%).

The most abundant arthropods, belonging to the order Amphipoda and Isopoda, were *Caprella scaura* (16%), *Corophium acherusicum* (12%), *Melita palmata* (9.1%), *Microdeutopus gryllotalpa* (8.5%) and *Gammarus insensibilis* (7.6%).

Statistical differences

Statistical differences were observed between the abundance values of the most representative taxa in the three station and the four months analysed. In particular, during January and April the presence of Polychaeta in station S3 decreased, while the abundances of Bivalvia and Gasteropoda increased showing statistical significant differences ($p<0.005$) to respect the other stations in these months. In October the abundance of Amphipoda showed the greatest values in station S1, while the Bivalvia reduced their importance with statistical significant differences ($p<0.005$)

Isopoda were found mostly in station S2 in July, then the differences between this station and all the others during this month were always significant ($p<0.05$) (Fig. 3).

Moreover, Polychaeta showed the lowest abundance values in station S1 and S2 during October, when in station S1 Amphipoda and Bivalvia and in station 2 Bivalvia increased their abundance, resulting in statistical significant differences ($p<0.005$) with the other seasonal samples in the same station. In station S3 Polychaeta showed the greatest value in July ($p<0.05$), while the Bivalvia and Gasteropoda were low represented and increased significantly in the other months.

The lowest number of specimens was found in the station closest to the sea (S1, N=3688), while similar values were found in the other two stations (S2, N=4724; S3, N=4619). It is also observed a decrease in the number of individuals from July (N=4885) to January (N=2214), while the number of taxa decreased regularly from station S1 (N=77) to station S3 (N=41), as Shannon diversity (S1=2.665; S3=2.450) and Margalef richness

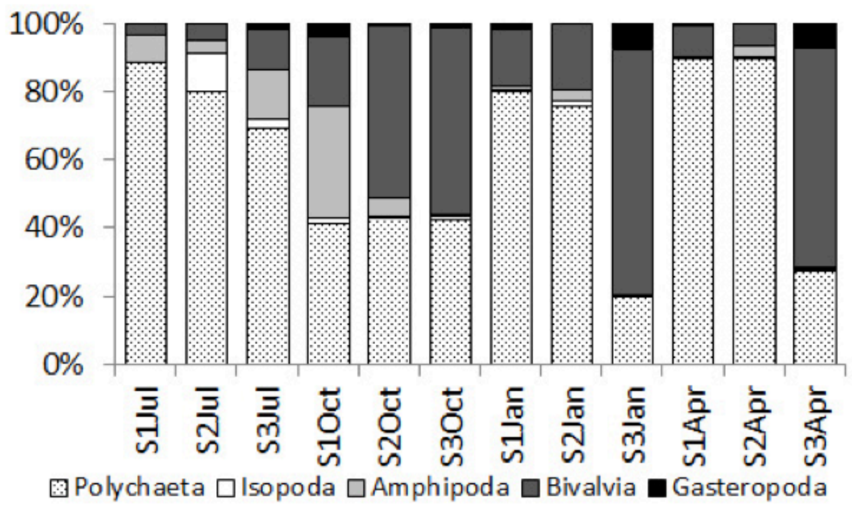

Figure 3. Frequency distribution of the 5 taxa in the different stations and months in the Santa Gilla lagoon.

(S1=9.254; S3=4.740). The greatest numbers of taxa were found in October (N=69) and the lowest in April (N=44). Similarly Shannon diversity and Margalef richness reaches a peak in October and then decreases from October to April (Fig. 4-5).

Discussion and Conclusions

In this study 52 taxa were collected and pointed out for the first time in Santa Gilla lagoon.

Report of new species in the Santa Gilla lagoon may depend on several factors. The first hypothesis is that most of them have not been observed previously due to the lack of specific studies that describe the entire macrozoobenthic community and investigate different sites of the area at different times. However, the presence of some species may represent a new introduction mainly due to anthropogenic activities.

The presence of Polychaeta species, such as *Capitella capitata*, *Heteromastus filiformis, Paraonis* sp., *Diopatra neapolitana*, *Nereis diversicolor*, *Prionospio cirrifera*, *Prionospio malmgreni*, *Pseudopolydora antennata*, *Phyllodoce rubiginosa*, *Sphaerosyllis* sp., *Streblospio shrubsolii* and *Cirriformia tentaculata*, was confirmed in this paper. On the other hand, polychaetes such *Capitella minima*, *Leocrates* sp., *Hydroides niger*, *Hydroides elegans* and *Spio filicornis* were recorded for the first time.

Likewise, the presence of amphipod species such as *Cyathura carinata*, *Sphaeroma serratum*, *Lekanesphaera hookeri*, *Microdeutopus gryllotalpa*, *Corophium insidiosum*, *Corophium orientale*, *Gammarus insensibilis* and *Melita palmata*, already recorded by Porcu *et al.* (1983), was ratified in this work. However, species such as *Hyale perieri*, *Monocorophium acherusicum* and *Caprella scaura* have never recorded before the present study. *Caprella scaura* is an alien species native to the Indian Ocean species and its introduction, through passive dispersal, is explained by its closeness to two ports and the activity of mussel farms, together with the reintroduction of the oyster *Ostrea edulis* in 2003 and of various allochthonous species, the clam *Ruditapes philippinarum* in 1996, the shrimp *Marsupenaeus japonicas* and the oyster *Crassostrea gigas* in 2004 (Cabiddu *et al.*).

In addition, species such as *Mytilus galloprovincialis*, *Cerastoderma glaucum*,

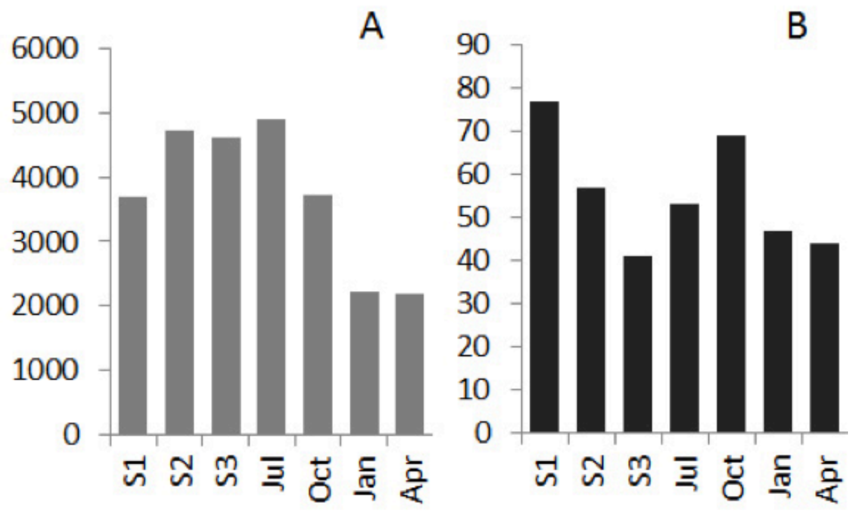

Figure 4. Number of individuals (A) and number of taxa (B) in the Santa Gilla lagoon.

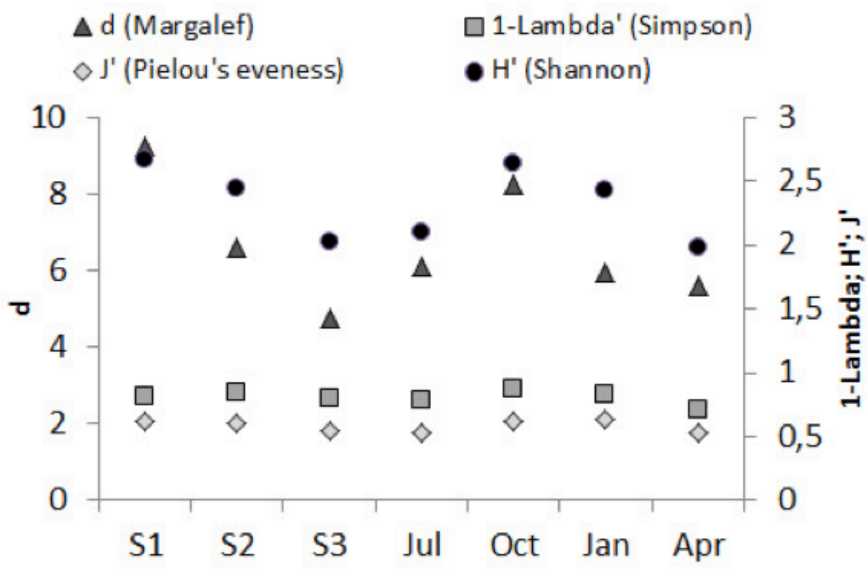

Figure 5. Margalef (d), Pielou (J'), Simpson (1-Lambda) and Shannon (H') indices values.

Ruditapes decussatus and *Cyclope neritea* was already collected, whereas *Ruditapes philippinarum*, *Arcuatula senhousia*, *Hydrobia* sp. and *Gibbula* sp. were registered for the first time.

R. philippinarum was introduced sperimentally for clam aquaculture in the Santa Gilla lagoon in 1987 (Cottiglia and Masala-Tagliasacchi, 1988), but it was known that the species did not find the optimal ecological condition for stabilization in the area. After this event the regional government of Sardinia have banned the semi-extensive use of *R. philippinarum* on beaches and lagoons. *A. senhousia*, is an alien species native to the Indopacific Ocean. In the Mediterranean area the presence of this species might be related to the transfer of Japanese oysters for aquaculture, as suggested by Mistri and Fano (2003). Later, it could have reached Sardinian lagoons through the introduction of bivalves coming from the Adriatic area (Atzori *et al.*, 2013).

Moreover, we analysed the differences on spatial and seasonal distribution of the macrobenthic fauna of the area. We found a great number of specimens belonging to different taxa. In particular, during the investigated year, the number of taxa and the diversity indeces values varied showing a peak in October and comparable values in the other months. Furthermore, the number of the taxa and the main diversity indeces values showed the same trend, with a gradual decrease from the station nearest to the sea to the station closed to the freshwater inflows, in the northern part of the lagoon.

Among the most representative phyla, Anellida Polychaeta showed the greatest abundance values in the two station nearest to the sea, while in the northern station characterized by lower values of salinity Mollusca Bivalvia dominated in the community.

Moreover Anellida Polychaeta were main present in spring and summer and their importance decreased in the other season, when Mollusca Bivalvia importance increased. These differences are common in coastal areas, where benthic assemblages often show great variability at different scales, which have been related to many different processes, such as interspecific relationships, recruitment and availability of food (Marsh and Tenore 1990; Posey and Hines 1991; Hunter and Price 1992; Posey *et al.* 1995).

In particular, among Anellida Polychaeta, the most abundant species resulted *S. shrubsolii*, an opportunistic species that colonise organically enriched sediments (Pearson and Rosenberg 1978; Cazaux 1985; Sarda' and Martin 1993).This species was found in all the stations investigated characterized by different salinity values (ranging from 15.0 to 34.0) as also observed by other authors (Cunha and Moreira, 1995; Cognetti and Maltagliati 2000; Kevrekidis, 2005) reporting that *S. shrubsolii* is among the species of marine origin usually found also in transitional waters of low salinity. Nevertheless, its number increased progressively in spring and summer according to Rossi and Lardicci (2002) that observed a strong influence of food in determining the numbers of *S. shrubsolii* in summer. In fact, population dynamics was regulated by the availability of food and individuals were likely to rapidly exploit the increases in food, suggesting that resources could play a relevant role in determining the small-scale distribution of deposit feeders.

Differently in autumn and winter Mollusca Bivalvia resulted the most abundant Taxa, cause the increase in number of two species: *A. alba* and *A. senhousia*.

The greatest number of specimens of *A. senhousia* was found in the station nearest to the freshwater sources, and the abundance increased significantly in autumn and winter seasons. This could be related with the life cycle of the species: the massive emission of gametes begins in September (Sgro and Mistri 2002), resulting in the appearance of recruits in autumn and winter, causing an increase of the population.

The other species that contribute to the differences observed in the different seasons is *A. alba*, showing the greatest number of specimens in the station nearest to the freshwater sources, as *A. senhousia*, and an increased number in autumn, when the population structure is dominated by young specimens. This trend may be related to the reproductive cycle of the species that could have a reproductive event during late summer /autumn. The species shows in Atlantic a reproductive peak in autumn and a second minor event in spring, with larval stage period of about three weeks (Crowe, 1985; O'Brien and Keegan, 2004).

In conclusion, this paper represent a first step in defining the community structure of Santa Gilla lagoon that could be used as base for further investigation in order to monitoring the status of the area.

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