

Spatial and seasonal distribution of ascidians in a semi-enclosed basin of the Mediterranean Sea

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A total of 25 species of ascidians were collected in the Mar Piccolo of Taranto, a semi-enclosed Mediterranean basin. Three are non-indigenous for the Mediterranean Sea: Microcosmus squamiger, Polyandrocarpa zorritensis and Distaplia bermudensis. The substrate features, season and depth affect the distribution of ascidians in the study area. Some species, such as Pyura dura and Pyura microcosmus, were found only on artificial substrates, while Ascidiella aspersa was almost exclusively recovered on natural bottoms. Seasonal variation in the ascidian distribution and abundance seems to be due mainly to their biological cycles, larval recruitment and adaptation. During the autumn and winter the most abundant species were Clavelina phlegraea and Ciona intestinalis, while A. aspersa was particularly abundant during spring. Depth and more directly light intensity play an important role in ascidian distribution. In the upper few metres the shallow-water species Polyandrocarpa zorritensis was abundant due to its photopositive larvae. Even though the distribution and abundance changed significantly between substrates, seasons and depths, the most abundant species in the Mar Piccolo of Taranto were Clavelina phlegraea, Ciona intestinalis and Styela plicata all of which are able to tolerate the variations in environmental conditions, low rate of water renewal and continuous silting of this semi-enclosed sea. Assuming the role that the above mentioned species have as marine pollution indicators and the abundance recorded for some of them, a high degree of environmental stress can be confirmed for the Mar Piccolo of Taranto. A comparative list of the ascidians recorded in this and previous studies is also reported.

Keywords: ascidians, benthic communities, Mediterranean Sea, *Microcosmus squamiger*, *Polyandrocarpa zorritensis*, *Distaplia bermudensis*, non-indigenous species

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INTRODUCTION

Ascidians are generally abundant in protected eutrophic habitats due to their feeding strategy as filter-feeders which make them particularly adapted to exploit the plankton as well as the dissolved and particulate organic matter which are very abundant in these habitats (Millar, 1971; Tursi, 1980). Moreover, many ascidian species are able to tolerate heavy environmental stresses such as those occurring in harbour areas (Brunetti & Menin, 1977; Naranjo *et al.*, 1996) and some of them have been considered as marine pollution indicators (Papadopoulou & Kaniyas, 1977; Naranjo *et al.*, 1996; Paparella *et al.*, 1996). The main studies on the ascidians in the Mar Piccolo of Taranto (eastern-central Mediterranean Sea) date back to the 1970s (Tursi *et al.*, 1974a, b, 1976, 1977, 1979; Matarrese *et al.*, 1980a, b). Such studies revealed that these tunicates are among the most common fouling species in the eutrophic waters of the Mar Piccolo of Taranto, often representing over 40% of the all benthic biomass.

Prior to the current study, 22 ascidian species were recorded and settlement phenomena and seasonal changes in abundance were investigated on the hard substrates of the Mar Piccolo of Taranto. In the last thirty years this semi-enclosed basin of the northern Ionian Sea has been subject to many anthropogenic activities, such as sewage outputs, industrial activities, intense naval traffic and mussel breeding (Cardellicchio *et al.*, 1991). Thus, the marine ecosystem and its benthic communities have been severely affected. In fact, the sea grass meadows of *Cymodocea nodosa* and *Posidonia oceanica* mapped by Parenzan (1969, 1983) have almost completely disappeared while a drifting nitrophilic algal bed is now widespread in the area (Cecere *et al.*, 1991, 1992). The abundance of some dominant indigenous species has been markedly reduced and several invasive exotic species including ascidians, have been recorded recently (Cecere *et al.*, 2000; Mastrototaro *et al.*, 2003; Cecere & Petrocelli, 2004; Brunetti & Mastrototaro, 2004; Mastrototaro *et al.*, 2004a, b; Mastrototaro & Dappiano, 2005; Mastrototaro & Brunetti, 2006). Furthermore, at present most of the bottoms in the Mar Piccolo of Taranto are covered with sludge and mud (Matarrese *et al.*, 2004).

The aim of this paper is to define the present qualitative and quantitative composition of the ascidian fauna in the Mar Piccolo of Taranto, in which both urban and industrial impacts occur, and evaluate their response to environmental stress.

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MATERIALS AND METHODS

The study area

The city of Taranto is located on the coast of the north-western Ionian Sea (eastern-central Mediterranean) (Figure 1). The Mar Piccolo is a semi-enclosed basin located to the north-east of the town and is made up of two inlets (I and II Seno) which cover an area of 20.72 km². Its maximum depth is 13 m in the first inlet (I Seno, mean = 9 m) and 9 m in the second (II Seno, mean = 4 m) (Matarrese *et al.*, 2004). Mainly in the second inlet there is a low rate of water renewal and an excess of silting and suspended matter (Cardellicchio *et al.*, 1991). The two inlets of the Mar Piccolo are characterized by reduced muddy bottoms with superficial debris of mussel shells and little stones covered by drift algal species (Cecere *et al.*, 1992; Matarrese *et al.*, 2004). Most of both inlets are occupied by mussel culture structures.

Sampling

The sampling area was a square of 250 m/side in the second inlet (II Seno) of the Mar Piccolo (Figure 1), in a region 3–4 m in depth. Sampling was carried out on both natural bottoms and artificial substrates. Seasonal samplings were carried out by SCUBA diving from December 2003 to November 2004 by two biologist divers. The study area was divided into 25 square sub-areas 50 m/side in size: 3 of these sub-areas were randomly selected each month. In order to investigate seasonal variation in the ascidian fauna, avoiding confusion between seasonal effects and uncontrolled source of variation, three randomly chosen dates within the same season were considered. All the ascidian species present in a square surface of 1600 cm² (40 × 40 cm) were collected in three spatial replicates for each sub-area. Thus, a total of 27 samples (3 dates × 3 quadrant replicates × 3 sub-areas) were obtained each season for a total of 108 samples in one

year. On the artificial substrates, consisting of the submerged chains of iron buoys and piles of the mussel culture structures near to the sampling area, sampling of the benthic organisms was carried out by scraping an area of about 400 cm² (40 × 10 cm) at three different depths of 0.5, 2 and 3.5 m, with two replicates for each depth. Thus, a total of 18 samples (3 dates × 2 replicates × 3 depths) were taken each season for a total of 72 samples in one year. Moreover, temperature (°C), dissolved oxygen (% of saturation), pH and salinity (psu) were recorded during each month in the water column (from 0.3 m to the bottom) of the study area using a multi-parametric probe. These environmental parameters together with other abiotic factors influencing ascidian distribution, such as hydrodynamism and suspended solid and organic matter, were assumed to be similar for all the sampling stations.

The ascidians were immediately anaesthetized with a saturated solution of menthol in seawater for a time varying from 2 to 4 hours according to the nature and size of the individual specimens and colonies. After this procedure, all specimens were preserved in 10% seawater-formalin and identified to species.

Data processing

The biomass of each ascidian species was measured by means of the volumetric method (McBurney, 1978). Each sample was plunged into a graduated measuring glass. The volume as biomass index (cm³/surface unit) was adopted as measuring the role of spatial competition among the benthic organisms.

A matrix of average biomass index data of the ascidian species (average of the replicates for each seasonal sample) per station was compiled using square root transformation. Ordination of the sampling stations according to the type of substrate (natural or artificial surfaces), season and depth, was performed by means of non-parametric multidimensional scaling (nMDS) based on Bray–Curtis similarity using the PRIMER 5 software (Clarke & Warwick, 2001). The four

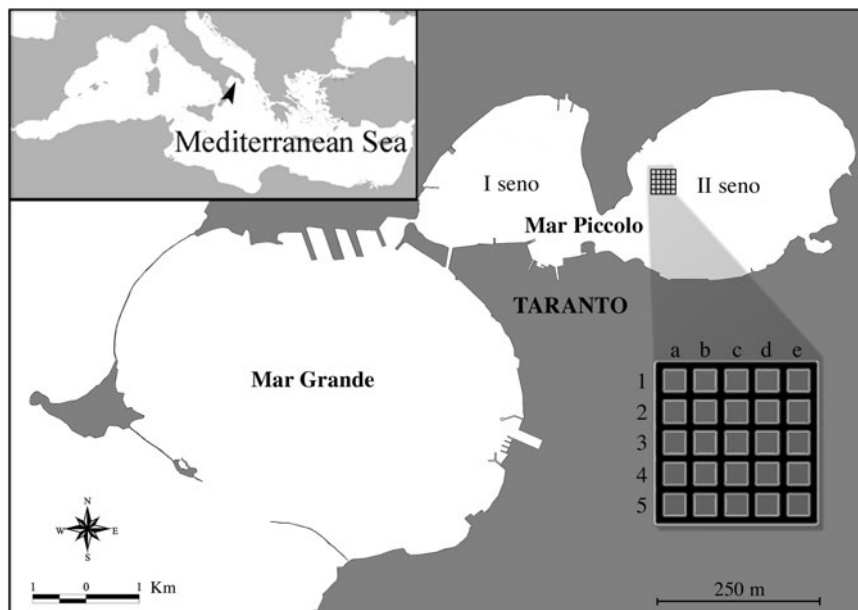


Fig. 1. Map of Taranto Seas with indication of the sampling area in the second inlet of the Mar Piccolo.

seasons were identified on the basis of mean water temperature, in particular October, November and December characterized the autumn (mean water temperature ranged from 12 to 22.5°C), January, February and March the winter (mean water temperature ranged from 8.5 to 12.2°C), April, May and June the spring (mean water temperature ranged from 17.33 to 24.53°C), July, August and September the summer (mean water temperature ranged from 24.19 to 26.22°C).

Analysis of similarities (ANOSIM) was applied to test the differences between the groups of the species–station. The pairwise test was carried out to evaluate the differences between levels. Individual species contributions (up to about 90%) to average similarity within each group identified were examined by the SIMPER procedure (Clarke & Warwick, 2001).

RESULTS

Average monthly values of 4 water parameters are shown in Figure 2. The mean water temperature showed a typical seasonal trend ranging from 8.6°C (January 2004) to 26.22°C (July 2004). The greatest mean value of dissolved oxygen was recorded in January 2004 (118.69%) while the smallest was measured in October of the same year (88.72%). The pH values were between 7.90 (November 2004) and 8.32 (August 2004) and the salinity ranged from 35.64 psu (March 2004) to 37.21 psu (July 2004).

A total of 25 ascidian species were found: 9 Aplousobranchia, 4 Phlebobranchia and 12 Stolidobranchia (Table 1). All but a *Botrylloides* sp. have been completely identified.

Multivariate analysis indicated the presence of two main groups of species–samples related to the different types of substrate: natural or artificial (Figure 3). The ANOSIM test confirmed that these two groups were significantly different with a global $R = 0.425$ ($P = 0.001$). From the SIMPER test, the samples collected on natural bottoms showed an average similarity of 23.26% and were mostly characterized by *Clavelina phlegraea* (32.84%), *Ciona intestinalis* (29.33%), *Styela plicata* (19.16%) and *Asciidiella aspersa* (13.36%) while those taken on artificial substrates showed an average similarity of 44.13% and mainly consisted of *C. phlegraea* (60.26%), *C. intestinalis* (11.21%), *Pyura dura* (8.35%), *S. plicata* (8.28%) and *Polyandrocarpa zorritensis* (6.43%).

The nMDS carried out for the samples collected on natural bottoms revealed the presence of four groups discriminated significantly by season (global $R = 0.58$; $P = 0.001$) (Figure 4). The pairwise test confirmed big differences between autumn versus spring ($R = 0.8$; $P = 0.001$), clear differences between winter versus spring ($R = 0.74$; $P = 0.001$), spring versus summer ($R = 0.72$; $P = 0.001$) and autumn versus winter ($R = 0.55$; $P = 0.001$), good differences between winter versus summer ($R = 0.47$; $P = 0.001$) and small differences between autumn versus summer ($R = 0.21$; $P = 0.013$). The SIMPER test carried out by season provided the following results: the autumn sample-group had an average similarity of 43.96% and was characterized by *C. phlegraea* (34.96%), *C. intestinalis* (34.33%), *S. plicata* (8.84%), *Phallusia mammillata* (7.16%) and *P. zorritensis* (6.47%); the winter sample-group had an average similarity of 44.09% and was characterized by *C. intestinalis* (48.85%) and *S. plicata* (43.38%); the spring assemblage showed an

average similarity of 38.16% and consisted almost exclusively of *A. aspersa* (94.12%); the summer cluster showed an average similarity of 32.57% and was mostly characterized by *C. phlegraea* (82.88%) and *C. intestinalis* (8.42%).

The nMDS carried out for the samples taken on the artificial substrates separated only two groups in relation to the different sampling depths, the first characterized by the samples carried out at surface (0.5 m) and the second characterized by the samples carried out in the water column (2 and 3.5 m) (global $R = 0.27$; $P = 0.001$) (Figure 5). In fact, the pairwise test provided good dissimilarities between the group of stations carried out at the surface (0.5 m) and those from 2 and 3.5 m in depth ($R = 0.43$; $P = 0.001$ and $R = 0.44$; $P = 0.001$ respectively) while no significant differences were detected between these two sample-groups (2 versus 3.5 m $R = -0.07$; $P = 0.947$). According to the SIMPER test, the group of stations at the surface showed an average similarity of 46.30% and was mainly characterized by *P. zorritensis* (38.48%), *C. phlegraea* (27.47%), *S. plicata* (14.37%) and *C. intestinalis* (10.61%), while the cluster of stations in the water column (2 and 3.5 m) had an average similarity of 52.60% and consisted mostly of *C. phlegraea* (69.62%), *P. dura* (11.12%), *C. intestinalis* (9.11%) and *S. plicata* (5.17%).

The seasonal factor was also considered in the nMDS carried out for the cluster of stations in the water column (2 and 3.5 m) indicating the presence of different groups, with a global $R = 0.55$ and highly significant differences ($P = 0.001$) (Figure 6). Also in this case, the pairwise test showed big differences between winter versus summer ($R = 0.87$; $P = 0.002$), clear differences between spring versus summer ($R = 0.73$; $P = 0.002$) and winter versus spring ($R = 0.59$; $P = 0.002$), good differences between autumn versus winter ($R = 0.47$; $P = 0.004$) and autumn versus spring ($R = 0.46$; $P = 0.006$) and small differences between autumn versus summer ($R = 0.22$; $P = 0.035$). The SIMPER test provided an average similarity of 64.34% for the autumn sample-group which was mostly characterized by *C. phlegraea* (68.57%), *P. dura* (16.08%) and *C. intestinalis* (5.88%). The winter sample-group had an average similarity of 58.15% and consisted mainly of *C. phlegraea* (47.64%), *S. plicata* (33.47%), and *C. intestinalis* (12.95%). The spring cluster showed an average similarity of 52% and was mostly made up by *C. phlegraea* (61.43%), *C. intestinalis* (15.86%), *Pyura microcosmus* (9.1%) and *A. aspersa* (5.22%). Finally, the summer sample-group showed an average similarity of 70.09% and was almost exclusively characterized by *C. phlegraea* (77.48%) and *P. dura* (14.12%).

No multivariate analysis was conducted for the surface group of stations due to the small number of samples.

DISCUSSION AND CONCLUSIONS

During this study 25 species of ascidians were collected in the Mar Piccolo of Taranto. Three are non-indigenous for the Mediterranean Sea: *Microcosmus squamiger*, probably of Australian origin (Kott, 1985; Lambert & Lambert, 1998; Monniot *et al.*, 2001; Turon *et al.*, 2007), was previously recorded in the Taranto Seas as *M. exasperatus* (Monniot, 1981; Mastrototaro & Dappiano, 2005); *Polyandrocarpa zorritensis*, a Pacific species originally described from Zorritos, Peru (Van Name, 1945) and first detected in

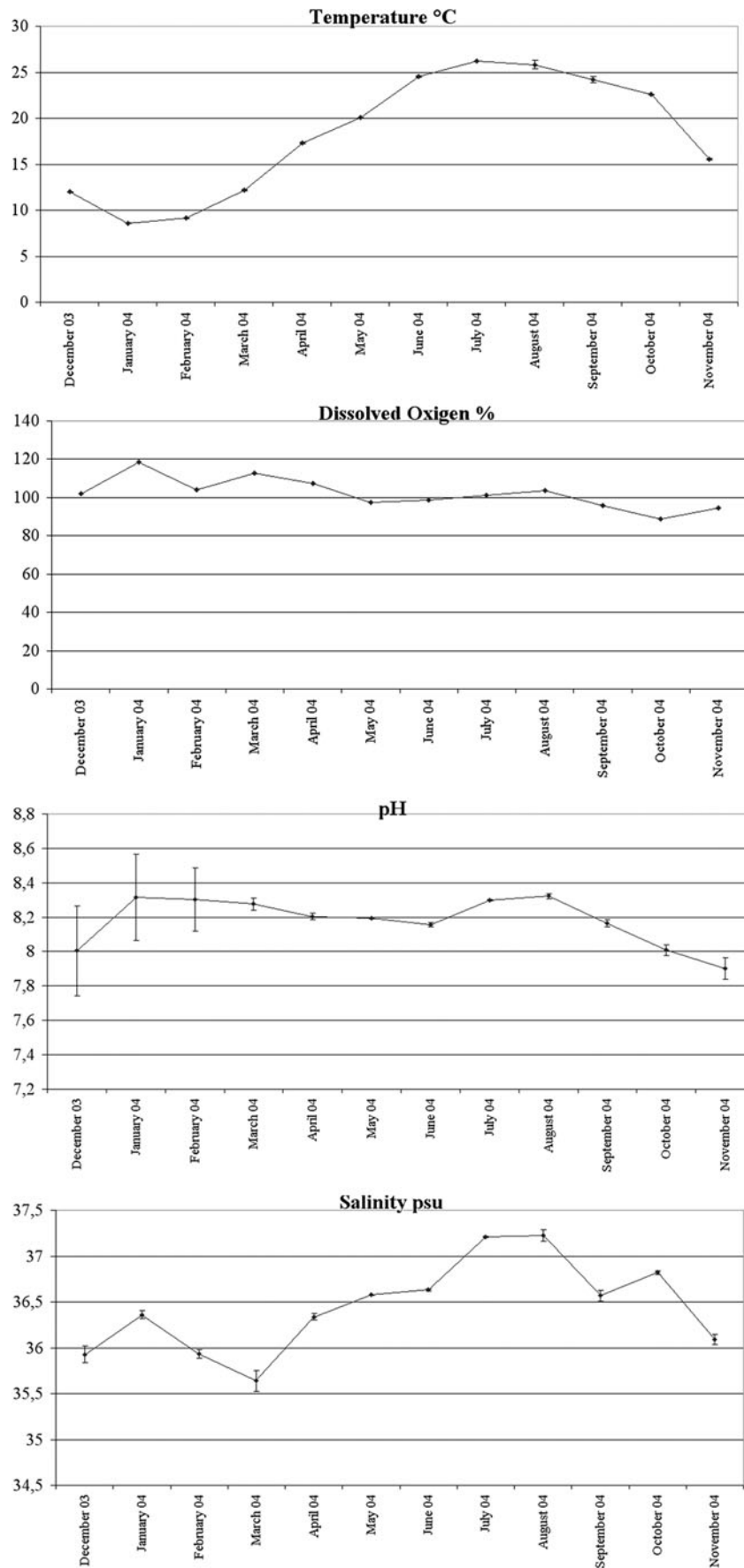


Fig. 2. Average monthly value (\pm SD) of the water parameters (temperature, dissolved oxygen, pH and salinity) recorded in the Mar Piccolo of Taranto.

Table 1. Average biomass index (cm³/m²) of the ascidian species seasonally collected in the Mar Piccolo of Taranto from December 2003 to November 2004 on natural bottoms at about 4 m depth and on artificial substrates at 0.5, 2 and 3.5 m depths.

| | Autumn | | | | Winter | | | | Spring | | | | Summer | | | |
|---|-------------------|--------|------------|---------|-------------------|--------|------------|---------|-------------------|--------|------------|---------|-------------------|---------|------------|---------|
| | Type of substrate | | | | Type of substrate | | | | Type of substrate | | | | Type of substrate | | | |
| | Natural | | Artificial | | Natural | | Artificial | | Natural | | Artificial | | Natural | | Artificial | |
| Aplousobranchia | 4 m | 0.5 m | 2 m | 3.5 m | 4 m | 0.5 m | 2 m | 3.5 m | 4 m | 0.5 m | 2 m | 3.5 m | 4 m | 0.5 m | 2 m | 3.5 m |
| <i>Clavelina phlegraea</i> Salfi, 1929 | 36.23 | 291.67 | 1354.17 | 1070.83 | 6.37 | 279.17 | 700.00 | 604.17 | 3.01 | 200.00 | 631.25 | 1183.33 | 145.02 | 1416.67 | 2000.00 | 1125.00 |
| <i>Distaplia bermudensis</i> Van Name, 1902 | 7.87 | 116.67 | 118.75 | 158.33 | | 8.33 | | | | | 83.33 | 20.83 | 9.84 | 272.92 | 241.67 | 160.42 |
| <i>Aplidium densum</i> (Giard, 1872) | 2.43 | 8.33 | 25.00 | | | 43.75 | | | 0.35 | 16.67 | 8.33 | | 0.81 | 4.17 | 2.08 | |
| <i>Aplidium turbinatum</i> (Savigny, 1816) | 2.20 | 14.58 | 10.42 | 16.67 | | 8.33 | | | 0.35 | 2.08 | 2.08 | | 0.58 | | | |
| <i>Didemnum maculosum</i> (Milne-Edwards, 1841) | | | 2.08 | | | 6.25 | 2.08 | 2.08 | | 6.25 | 2.08 | 2.08 | | 4.17 | | |
| <i>Diplosoma listerianum</i> (Milne-Edwards, 1841) | 0.23 | | | | | 2.08 | 4.17 | 2.08 | | 8.33 | | | 0.46 | 2.08 | 4.17 | 6.25 |
| <i>Lissoclinum perforatum</i> (Giard, 1872) | | | 2.08 | | | 6.25 | 2.08 | 2.08 | | 6.25 | 2.08 | 2.08 | | 4.17 | | |
| <i>Polysyncrator bilobatum</i> Lafargue, 1968 | | 2.08 | 8.33 | 4.17 | | 4.17 | 4.17 | | | | | | | 2.08 | 2.08 | 2.08 |
| <i>Trididemnum cereum</i> (Giard, 1872) | | | 2.08 | 2.08 | | 6.25 | 2.08 | 2.08 | | 6.25 | 4.17 | 2.08 | | 2.08 | 2.08 | |
| Phlebobranchia | | | | | | | | | | | | | | | | |
| <i>Ciona intestinalis</i> (Linnaeus, 1767) | 36.00 | 16.67 | 129.17 | 225.00 | 43.52 | 289.58 | 395.83 | 108.33 | 0.93 | 368.75 | 322.92 | 343.75 | 35.60 | 56.25 | 114.58 | 54.17 |
| <i>Asciidiella aspersa</i> (Müller, 1776) | 1.50 | | 2.08 | 10.42 | 1.90 | | | 2.08 | 31.53 | 20.83 | 150.00 | 62.50 | 0.35 | 16.67 | 2.08 | |
| <i>Asciidiella scabra</i> (Müller, 1776) | 0.46 | | | | | | | | | | | | 0.69 | | | |
| <i>Phallusia mammillata</i> (Cuvier, 1815) | 6.25 | | | | | | | | 0.69 | 12.50 | | | 0.69 | | | |
| Stolidobranchia | | | | | | | | | | | | | | | | |
| <i>Botrylloides leachi</i> (Savigny, 1816) | 0.23 | 4.17 | 2.08 | | | 2.08 | | 2.08 | 0.12 | 85.42 | 25.00 | 2.08 | | 37.50 | | |
| <i>Botrylloides</i> sp. | 1.62 | | | | | | | | 0.12 | 6.25 | 18.75 | | | | | |
| <i>Botryllus schlosseri</i> (Pallas, 1766) | 1.62 | | 6.25 | | | | | | | 54.17 | | | | 18.75 | | |
| <i>Polyandrocarpa zorritensis</i> (Van Name, 1931) | 7.29 | 616.67 | | 75.00 | | 70.83 | | 62.50 | | 479.17 | 116.67 | 54.17 | 2.08 | 866.67 | | |
| <i>Styela canopus</i> (Savigny, 1816) | 0.46 | 39.58 | 18.75 | | 0.12 | 29.17 | | | | 64.58 | 64.58 | 22.92 | 0.46 | | | |
| <i>Styela plicata</i> (Lesueur, 1823) | 29.51 | 137.50 | 62.50 | 210.42 | 40.28 | 172.92 | 353.33 | 1220.83 | 1.85 | 137.50 | 66.67 | 58.33 | 15.74 | 175.00 | | 20.83 |
| <i>Microcosmus claudicans</i> (Savigny, 1816) | | | | | | | | | | | | | 0.23 | | | |
| <i>Microcosmus nudistigma</i> Monniot C., 1962 | | | | | | | | | | | | | | | | |
| <i>Microcosmus polymorphus</i> Heller, 1877 | | | 8.33 | 6.25 | | 41.67 | | 4.17 | | | | | | | | 125.00 |
| <i>Microcosmus squamiger</i> (Hartmeyer & Michaelsen, 1928) | | 6.25 | 20.83 | | | 50.00 | | | | | | | 0.23 | | | |
| <i>Pyura dura</i> (Heller, 1977) | 0.46 | 50.00 | 362.50 | 331.25 | 0.16 | 122.92 | 250.00 | 108.33 | | | 104.17 | 329.17 | 0.46 | 50.00 | 345.83 | 254.17 |
| <i>Pyura microcosmus</i> (Savigny, 1816) | | | 25.00 | 6.25 | | 37.50 | 6.25 | 4.17 | | | 110.42 | 329.17 | | | 33.33 | 4.17 |

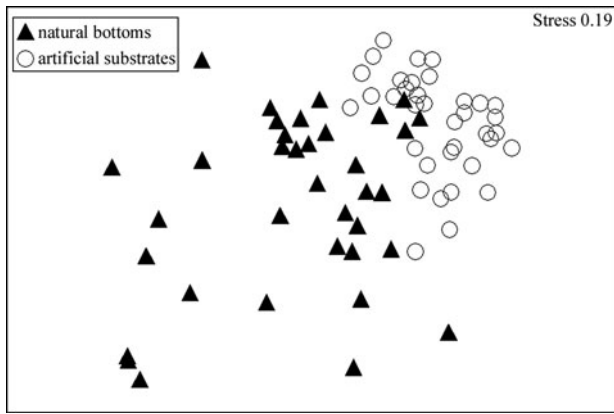


Fig. 3. Non-parametric multidimensional scaling ordination of the ascidian biomass sampled on different type of substrates (▲, natural bottoms; ○, artificial substrates).

the Mediterranean by Brunetti (1978–79), and *Distaplia bermudensis* of Atlantic origin (Van Name, 1945). These latter two species have been recently recorded in the Mar Piccolo of Taranto (Brunetti & Mastrototaro, 2004; Mastrototaro & Brunetti, 2006).

In comparison with the list reported in the literature (Tursi *et al.*, 1974b; Matarrese *et al.*, 1980a, b; Tursi & Scalera Liaci, 1983) (22 species), 13 are common and 12 are new findings (Table 2). The differences observed seem to be mostly due to the presence of non-indigenous species recently recorded and to those species of new taxonomic revision and classification (Monniot 1981; Brunetti, 1987; Brunetti & Mastrototaro, 2004; Mastrototaro & Brunetti, 2006).

The spread of non-indigenous species in the Mediterranean has increased in recent years (Galil, 2000; Occhipinti Ambrogio, 2001) and the Mar Piccolo of Taranto is one of many inner basins affected by this phenomenon (Cecere *et al.*, 2000; Mastrototaro *et al.*, 2003; Brunetti & Mastrototaro 2004; Cecere & Petrocelli, 2004; Mastrototaro *et al.*, 2004a, b; Mastrototaro & Dappiano, 2005; Mastrototaro & Brunetti, 2006). Most probably, the continuous instability, due to environmental stresses in the Mar Piccolo of Taranto, favours the introduction of opportunistic species which often become dominant due to the lack of

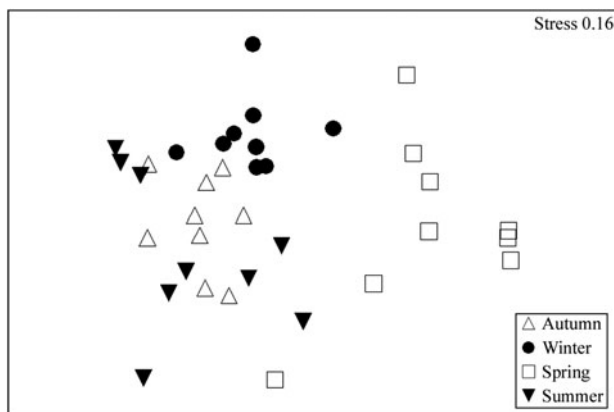


Fig. 4. Non-parametric multidimensional scaling ordination of the ascidian biomass sampled on natural bottoms during the four seasons (△, autumn; ●, winter; □, spring; ▼, summer).

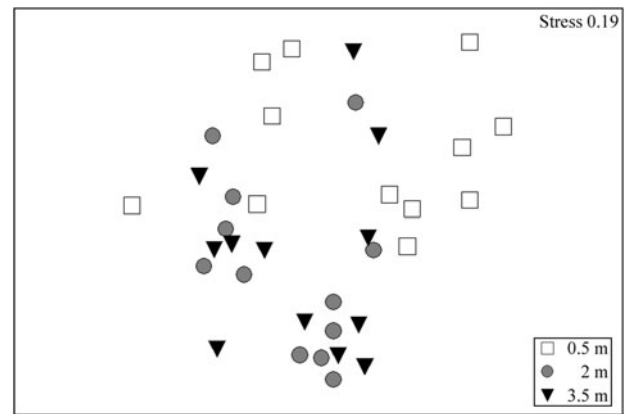


Fig. 5. Non-parametric multidimensional scaling ordination of the ascidian biomass sampled on artificial substrates at three different depths (□, 0.5 m; ●, 2 m; ▼, 3.5 m).

natural predators or competitors (Mistri, 2002; Matarrese *et al.*, 2004). *Clavelina lepadiformis* reported by Tursi *et al.* (1974b), even if still present in some areas of the Mar Piccolo (Mastrototaro, personal observation) seems to have been replaced in most areas by the co-generic *C. phlegraea*. Concerning the restricted investigated area, the absence in this study of some species of ascidians previously recorded (Tursi *et al.*, 1974b; Matarrese *et al.*, 1980a, b; Tursi & Scalera Liaci, 1983) does not mean that they have disappeared from the Taranto Seas.

The substrate features, seasons and depths seem to affect the distribution of ascidians in the Mar Piccolo of Taranto, confirming previous observations in the same and other marine areas (e.g. Tursi *et al.*, 1974a, b; Brunetti & Menin, 1977; Matarrese *et al.*, 1980a, b; Naranjo *et al.*, 1996). Variations in climatic and physical–chemical factors, such as light, temperature and salinity, linked to substrate type, seasons and depths influence the biological cycles and the release of larvae as well as their behaviour and settlement (e.g. Watanabe & Lambert, 1973; Tursi *et al.*, 1976; Brunetti & Menin, 1977; Svane, 1984; Turon, 1988; Svane & Young, 1989).

Some species, such as *Pyura dura* and *P. microcosmus*, were found to be abundant on chains and piles while they were not

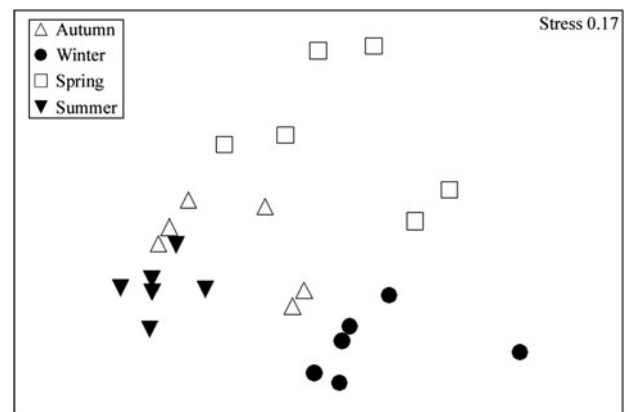


Fig. 6. Non-parametric multidimensional scaling ordination of the ascidian biomass sampled on artificial substrates in the water column (2 and 3.5 m) during four seasons (△, autumn; ●, winter; □, spring; ▼, summer).

Table 2. Comparison between the lists of ascidian species found in the literature (Tursi *et al.*, 1974b; Matarrese *et al.*, 1980a, b; Tursi & Scalera Liaci, 1983) and the present study.

| Ascidian species | Literature | Present study | Common species |
|---------------------------------------|------------|---------------|----------------|
| <i>Aplidium densus</i> | | * | |
| <i>Aplidium turbinatum</i> | | * | |
| <i>Ascidia mentula</i> | * | | |
| <i>Asciidiella aspersa</i> | * | * | * |
| <i>Asciidiella scabra</i> | * | * | * |
| <i>Botrylloides leachi</i> | * | * | * |
| <i>Botrylloides</i> sp. | | * | |
| <i>Botryllus schlosseri</i> | * | * | * |
| <i>Ciona intestinalis</i> | * | * | * |
| <i>Clavelina lepadiformis</i> | * | | |
| <i>Clavelina phlegraea</i> | | * | |
| <i>Didemnum maculosum (=candidum)</i> | * | * | * |
| <i>Diplosoma listerianum</i> | * | * | * |
| <i>Distaplia bermudensis</i> | | * | |
| <i>Distaplia magnilarva</i> | * | | |
| <i>Distomus variolosus</i> | * | | |
| <i>Lissoclinum perforatum</i> | * | * | * |
| <i>Microcosmus claudicans</i> | * | * | * |
| <i>Microcosmus nudistigma</i> | | * | |
| <i>Microcosmus polymorphus</i> | | * | |
| <i>Microcosmus savignyi</i> | * | | |
| <i>Microcosmus squamiger</i> | | * | |
| <i>Microcosmus vulgaris</i> | * | | |
| <i>Phallusia mammillata</i> | * | * | * |
| <i>Polycarpa pomaria</i> | * | | |
| <i>Polycarpa gracilis</i> | * | | |
| <i>Polyandrocarpa zorritensis</i> | | * | |
| <i>Polysyncraton bilobatum</i> | | * | |
| <i>Pyura dura</i> | * | * | * |
| <i>Pyura microcosmus</i> | | * | |
| <i>Pyura squamulosa</i> | * | | |
| <i>Styela canopus</i> | * | * | * |
| <i>Styela plicata</i> | * | * | * |
| <i>Trididemnum cereum</i> | | * | |
| Total | 22 | 25 | 13 |

collected on natural bottoms. On the contrary, *A. aspersa* was almost exclusively recovered on natural bottoms. Seasonal variation in distribution and abundance could be mainly due to their biological cycles, larval recruitment and adaptation. During the autumn and winter the most abundant species were *C. phlegraea* and *C. intestinalis*, confirming previous observations (Tursi *et al.*, 1974a; Liaci *et al.*, 1977), while *A. aspersa* was particularly abundant during spring. This species seems to be capable of tolerating the increase in algal biomass during spring (up to 95% of the total biomass) (*Chaetomorpha linum*, *Cladophora hutchinsiae*, *Ulva* spp.) (Matarrese *et al.*, 2004) since its larval forms are able to settle on the algal surface. Depth and more directly light intensity play an important role in ascidian distribution (Svane & Young, 1989). In fact, in the first metres of depth the shallow-water species *Polyandrocarpa zorritensis* was found to be abundant due to its photopositive larvae (Vazquez & Young, 1998).

Even though distribution and abundance changed significantly between substrates, seasons and depths, the most abundant species in the study area were *C. phlegraea*, *C. intestinalis* and *S. plicata*. These species are able to tolerate large variations in environmental conditions, low rate of water renewal and continuous silting. Indeed, *C. phlegraea* can

survive environmental stress thanks to its ability to generate resistant forms (Salfi, 1929, 1931; Brunetti, 1987); *C. intestinalis* with its filter-feeding ability is capable of living in water with a very low rate of renewal (Tursi *et al.*, 1974a; Liaci *et al.*, 1977), and *S. plicata* with its thick tunic and ability to raise the viscera and branchial sac is able to tolerate the high sedimentation rate (Tursi *et al.*, 1974b, 1976, 1979).

Based on their response to environmental stress, Naranjo *et al.* (1996) classified the ascidians in Algeciras Bay, southern Spain as: 'regressive species' (those living in natural and non-perturbed habitats which disappear or reduce their populations when stress increases); 'transgressive species' (those that are dominant in harbour areas and in zones with highly modified substrates, a low rate of water renewal and excess silting and suspended matter, commonly pioneers and opportunists, typical of bio-fouling); and 'tolerant species' (those capable of living under almost any conditions, colonizing both natural rocks in the outer zone of the bay and vertical walls of ports, generally absent from internal harbour areas with low water movement). Many species found in the Mar Piccolo of Taranto belong to the second and third categories. In particular, *C. intestinalis*, *P. mammillata*, *M. squamiger* and *S. plicata* are categorized as 'transgressive species'. Also *P. zorritensis* might be added to this category considering

its tolerance and adaptation to the physical–chemical changes of the waters (Brunetti, 1978–79); it has become quite common in a number of harbours in southern California (Lambert & Lambert, 2003). The species *A. aspersa*, *Botryllus schlosseri*, *Botrylloides leachi* and *Diplosoma listerianum* are included in the category of ‘tolerant species’.

Assuming the role that the above mentioned species have as marine pollution indicators (Papadopoulou & Kaniyas, 1977; Naranjo *et al.*, 1996) and the abundance recorded of some of them, a high degree of environmental stress can be confirmed for the Mar Piccolo of Taranto as observed in another study carried out recently in this semi-enclosed sea (Matarrese *et al.*, 2004).

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