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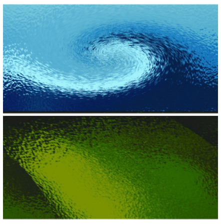

RESEARCH ARTICLE

Renewal time in a population of *Abra segmentum* (Mollusca, Bivalvia): a case of marked *r* strategy

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Abstract

1 - *Abra segmentum* is a common and frequently abundant species in the Mediterranean coastal lagoons, playing a dominant role, both in numbers and biomass, in the infauna of these habitats and is an important food for a variety of species.

2 - The main objective of this work is to describe the renewal time of *Abra segmentum* in Lesina lagoon. The insurgence of hydrogen sulphide which exterminated the benthic macrofauna in an area of Lesina lagoon during July 2008 allowed us to accurately observe the re-colonization time of this bivalve. In order to achieve this aim, the population structure and spatial distribution of *A. segmentum* before and after the dystrophic crisis were investigated in the entire Lesina lagoon and, in detail, in the area affected by the crisis.

3 - 51 sampling units were collected in Lesina lagoon in May and October 2008, allowing to compare the situation before and after the dystrophic crisis. The length-frequency distribution showed the existence of two size groups in both May and October 2008. The individuals were counted, their individual length measured and their total wet biomass weighed.

4 - The total number of individuals decreased after the crisis in the entire lagoon, but this drop was strongly observed in the perturbed area. The length-frequency distribution showed the existence of two size groups in both May and October 2008. After dystrophic crisis, the two size groups were clearly separated and juveniles group (2-5 mm) was located in the area interested by dystrophic event.

5 - The results obtained in this study highlight the rapidity of re-colonisation of *A. segmentum* after the strong disturbance caused by the insurgence of dystrophic crisis. The dynamics of the population was particularly clear when considering the area affected by the dystrophic crisis. In May the population was structured as in the rest of the lagoon, but in October there was a marked difference. The insurgence of a dystrophic crisis in Lesina lagoon allowed to clearly observe the resilience of *A. segmentum* to environmental stress, confirming it as an *r* strategy species.

Keywords: *Abra segmentum*; Dystrophic crisis; Lesina lagoon; Population structure; Renewal time; *r* strategy.

Introduction

The bivalve *Abra segmentum* (Recluz, 1843) is a shallow-water species with a geographical range extending from the Atlantic coasts of Morocco and France to the Mediterranean Sea, the Black Sea, the Caspian Sea and the Aral Sea (Denis 1981; Kiseleva *et al.* 1996; Aladin *et al.* 1998; Latypov 2004; Nicolaidou *et al.* 2006). This infaunal, deposit-feeding bivalve lives in waters which may vary from oligohaline to hyperhaline (Marazanof 1969; Gremare *et al.* 2004; Kevrekidis 2004). It is a common and frequently abundant species in the Mediterranean coastal lagoons, playing a dominant role, both in numbers and biomass, in the infauna of these habitats and is an important food for a variety of species (Cottiglia *et al*. 1983; Kevrekidis *et al*. 1990; Bedulli and Sabelli, 1990; Sprung, 1994; Kevrekidis 2004; Nicolaidou et al. 2006; Ponti *et al*. 2007, Breber *et al*., 2001). In addition, this bivalve, reaching high densities and displaying a high sediment reworking rate per individual, may account for a significant part of sediment re-working occurring in Mediterranean lagoons (Maire *et al*. 2007). Because of its significant role in brackish-water coastal ecosystems, *A. segmentum* has become one of the most studied macroinvertebrate species in these environments. This species is characterised by one drawn out recruitment over the year with some variation probably related to water temperature, local factors and physiological differences between populations (Kevrekidis *et al*., 1992). In general, two different life strategies have been reported. Bachelet (1986) describe a prolonged period of reproduction, a short planktonic phase and a long meiobenthic phase (3-6 months) with two generations per year and a longevity of 1-2 years. On the other hand, Sprung (1994) reported a short reproductive period, direct development, a short meiobentic phase, one generation per year and a longevity of 1 year. Reizopoulou and Nicolaidou (2007) suggest that either *A. segmentum* adopts the former life strategy in confined lagoons and the latter one in coastal habitats, or else it is a case of sibling species. Our observations concur with Bachelet. (1986). Research topics involve, among others, reproductive biology, life history, demography, growth, population dynamics and secondary production (Denis 1981; Guelorget and Mazoyer-Mayere 1982; Nicolaidou and Kostaki-Apostolopoulou 1988; Sprung 1994; Reizopoulou and Nicolaidou 2007). However, to our knowledge, these aspects of the biology and ecology of *A. segmentum* have been studied in mesohaline, polyhaline or/and euhaline environments, but not in extremely low salinity habitats; sub-lethal salinities may be important physiological constraints on reproduction and growth and determinants of life history patterns and population dynamics of macrobenthic invertebrates in brackish water habitats (Cunha *et al*. 2000). Like Mediterranean lagoons in general, Lesina is a stressful and fluctuating habitat (Quignard, 1984), and those organisms that inhabit it during their entire life cycle are necessarily *r* strategists. The main objective of this work is to describe the renewal time of *Abra segmentum* in Lesina lagoon. The insurgence of hydrogen sulphide which exterminated the benthic macrofauna in an area of Lesina lagoon during July 2008 allowed us to accurately observe the re-colonization time of this bivalve. In order to achieve this aim, the population structure and spatial distribution of *A. segmentum* before and after the dystrophic crisis were investigated in the entire Lesina lagoon and, in detail, in the area affected by the crisis.

Materials and methods

Study area

Lesina lagoon is located on the northern coast of the Gargano Promontory (Southern Adriatic Sea) (41.88°N; 15.45°E) (Figure1). It extends to 5500 ha with an average depth of 0.6 m. There are two channels (Schiapparo and Acquarotta) connecting it with the sea. Exchange caused by the tides is feeble due to low excursions (± 20 cm) (Ficca, 1995; Marolla *et al*., 1996) whereas the NNW winds which blow frequently in winter are more effective in bringing in seawater. Three large karst springs (Caldoli, Lauro, Fiume Lungo) contribute freshwater. Residence time of the water is estimated in 70-100 days (Manini *et al*., 2002). Strong seasonal variations of temperature (7◦C in winter and 26-32◦C

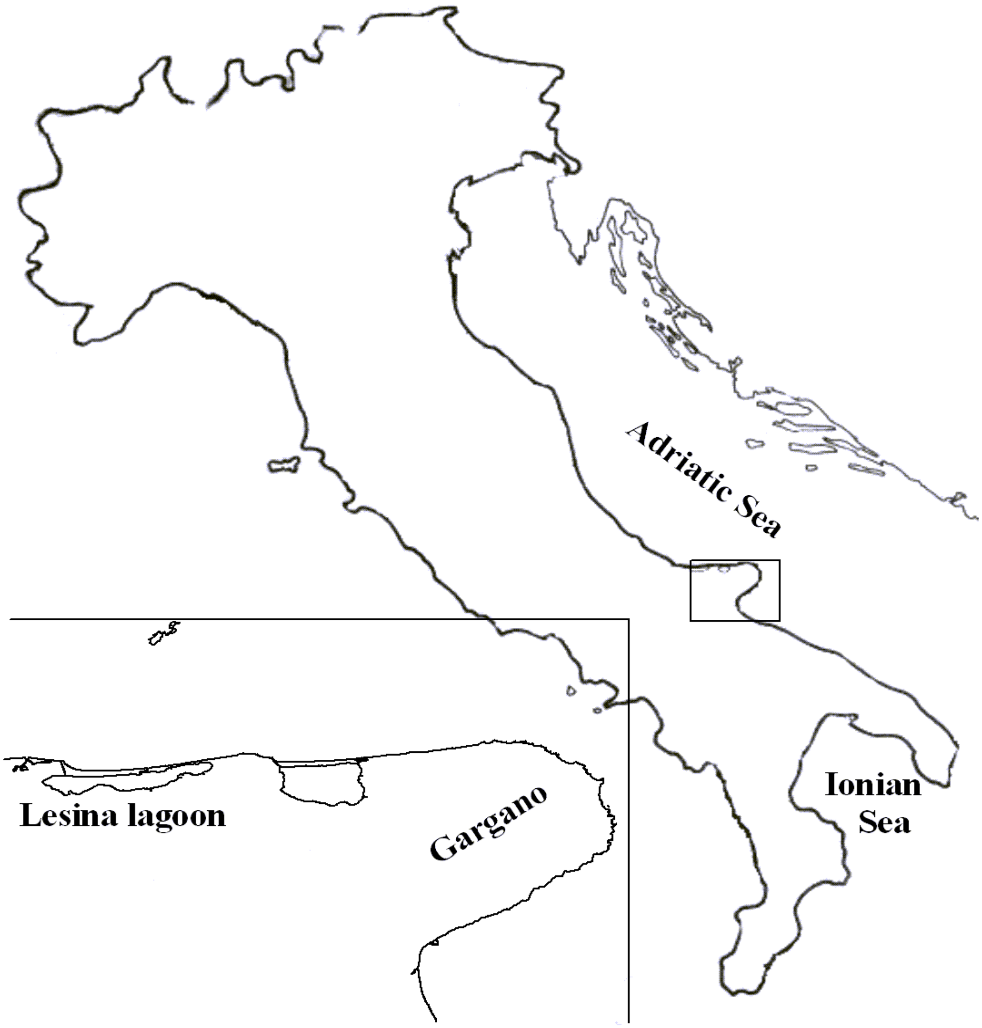

Figure 1. Investigation area Italy - Gargano

in summer) and salinity (from 5 to 34 psu) characterize the Lesina lagoon (Marolla *et al*. 1996; Priore *et al*. 1994, Caroppo, 200; Specchiulli *et al*.). The near totality of the sediments is sandy silt with only a limited western area of silt. Sand and silty sand are practically absent. (Brambati *et al*. 2002). The western part of the lagoon generally exhibits higher salinity values compared to the eastern area where the freshwater springs are situated. Although the overall environmental status may be considered good, the lagoon is not immune from pollution. Tainted water comes in from a water buffalo farm, from finfish aquaculture plants, from sewage treatment plants from three towns and from a polder pumping station draining industrially cultivated land.

Sampling

In order to get a complete picture of the population structure of *A. segmentum* in

Lesina lagoon, we adopted the sampling scheme suggested by Cuff and Coleman (1979), according to which it is preferable to take one sampling unit per station but many stations rather than fewer stations and several replicates per station. Our sampling operation, therefore, comprised 51 sampling units taken from the same number of equally spaced stations (Figure 2).

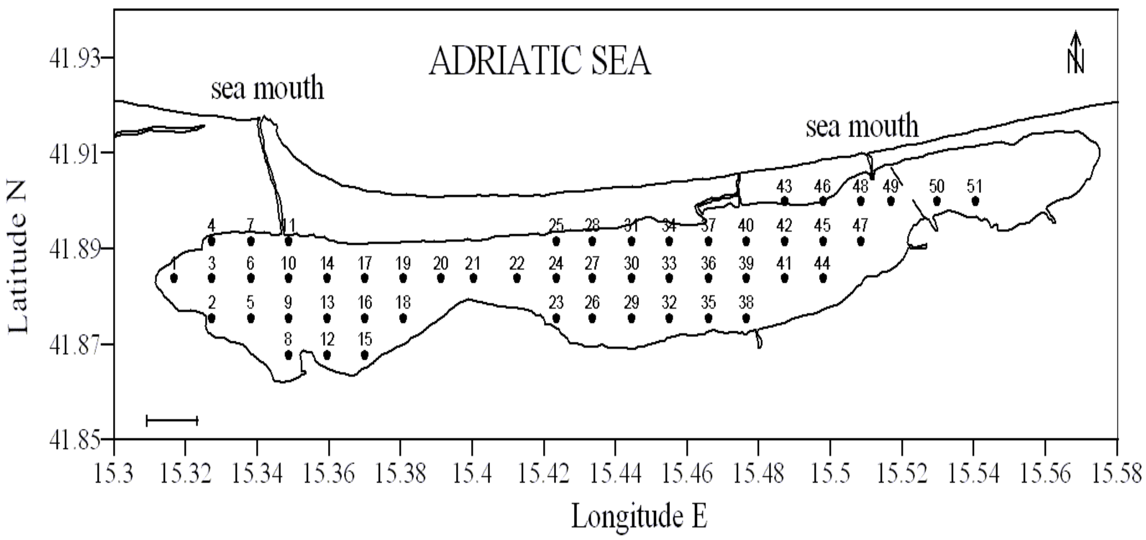

Figure 2. Location of 51 sampling units in Lesina lagoon.

The sampling instrument was a box-corer, and the sampling unit consisted in the individuals of *A. segmentum* gathered from an area of sediment 15 x 15 cm, to the depth of 15 cm, and held by a 1 mm mesh.
The individuals were counted, their individual length measured (±1mm) and their total wet biomass weighed (±0.001g). Samples were taken in May and October 2008 thus allowing us to compare the situation before and after the dystrophic crisis at the end of June.

Population structure analysis and spatial distribution
On the basis of shell length, individuals were aggregated into 1 mm size classes. The analysis of the population structure was performed by means of the Modal Progression Analysis of Bhattacharya (1967), using the FISAT software package (Gayanilo and Pauli, 1997). Spatial distribution of relative abundance were obtained using the Surfer 8 software.

Statistical analysis
The similarity among stations was investigated using non-metric multidimensional scaling (MDS) (Kruskall and Wish, 1964) based on the Bray-Curtis similarity with log transformation of data.

Results
Population structure analysis
Some biometric parameters, the total number of individuals and the percentage of coverage of *A. segmentum* in Lesina lagoon before (May 2008) and after (October 2008) the dystrophic crisis are reported in Table 1. The total number of individuals decreased after the crisis in the entire lagoon, but this drop was strongly observed in the perturbed area. The percentage of coverage of *A. segmentum* decreased slightly after crisis in the whole

Table 1 - Biometric parameters, the total number of individuals and the percentage of coverage of *A. segmentum* in Lesina lagoon before (May 2008) and after (October 2008) the dystrophic crisis.

	Whole lagoon		Sub-Area	
	May 2008	**October 2008**	**May 2008**	**October 2008**
Tot. Ind	1713	764	893	268
N° mean Ind.m^{-2}	1466	664	2203	661
Mean	9	8	9	6
Min length	2	2	2	2
Max length	16	17	15	16
Mode	10	9	10	5
Median	10	8	9	6
coverage %	86	74	100	33

lagoon, while the perturbed area showed a decreasing of about 60%. Biometric data indicate no evident difference related to both the typology of area and observation period. To better highlight biometric differences, the length-frequency analysis was performed before and after the dystrophic event and the related histograms are shown in Figure 3. The length-frequency distribution showed the existence of two size groups in both May and October 2008. In May, the less numerous group showed a mean length of 4 ±1 mm, while the more numerous presented a mean length of 9 ±2 mm. The most frequent size class was 10 mm, with a mean density of 542±786 ind/m^2.

The smallest size class had a shell length of 2 mm and a density 1 ind/m^2. The largest A. segmentum individuals having a shell length of 16 mm show a density of 1 ind/m^2.

In October, the two size groups were clearly separated, presenting a mean size of 6±1 mm and 10±2 mm, respectively. The most frequent size was 9 mm with a mean density of 154±304 ind/m^2. The smallest individual found had a shell length of 2 mm with spatial density 11 ind/m^2. The largest *A. segmentum* individuals had a shell length of 17 mm and spatial density of 1 ind/m^2. The analysis of percentage composition of size class of *A. segmentum* showed that the May sample contained 1713 individuals, 50% of which ranged within 10-14 mm size class (Figure 4), while in the October sample, 764 individuals were found and 43% of which ranged within the 2-5 mm size (Figure 5). This analytical procedure was run only on the sampling units (18 units) taken from the area in which the dystrophic crisis occurred. The population structure in this area, before and after the crisis, is shown in Figure 6. In May, the population structure of this sub-sample is the same as that of the entire sample (51 units): the first curve describes a group having a mean size of 6±1 mm and the second curve a group showing a mean size of 10±2 mm.

The most frequent size class was 10 mm having a density of 844±1071 ind/m^2.

In October, the size distribution curve showed a main group presenting a mean size of 5 ±2 mm, with a small residual group with a mean size of 12±2 mm. The most numerous size class was 5 mm, with a mean density of 128±378 ind/m2. In May the sub-sample

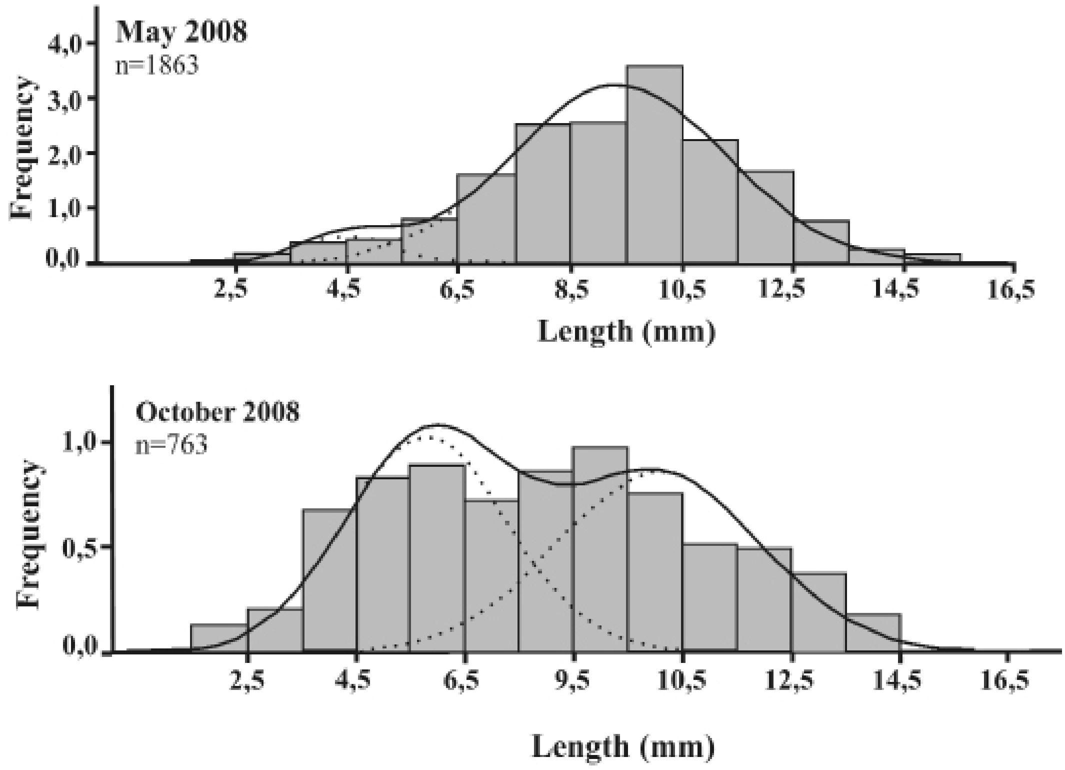

Figure 3. Length- frequencies distribution of Abra segmentum in Lesina lagoon from specimens

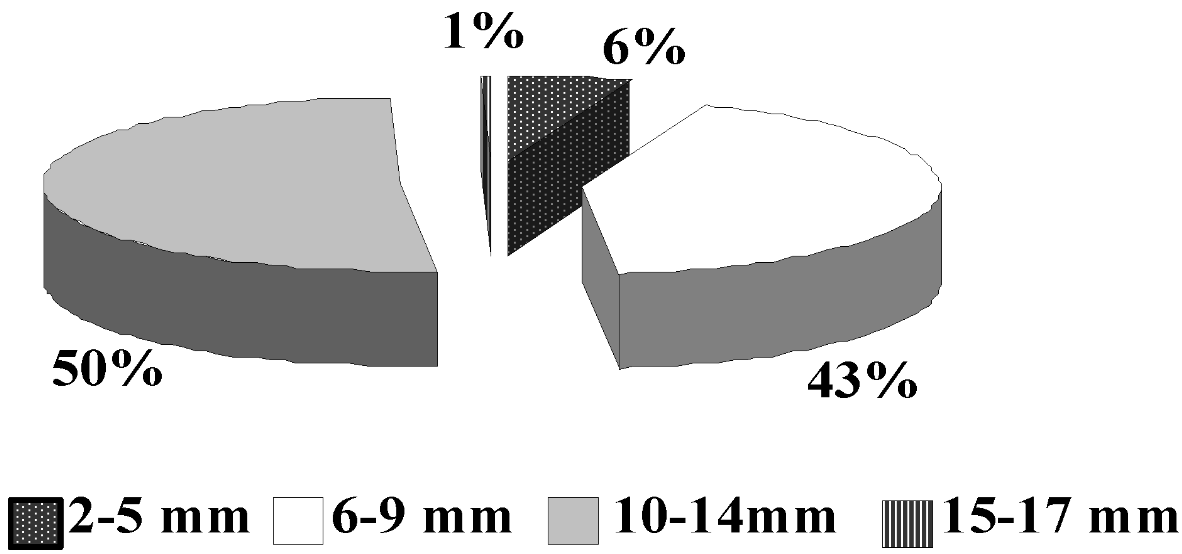

Figure 4. Percentage composition of size class of *Abra segmentum* in Lesina lagoon- May 2008

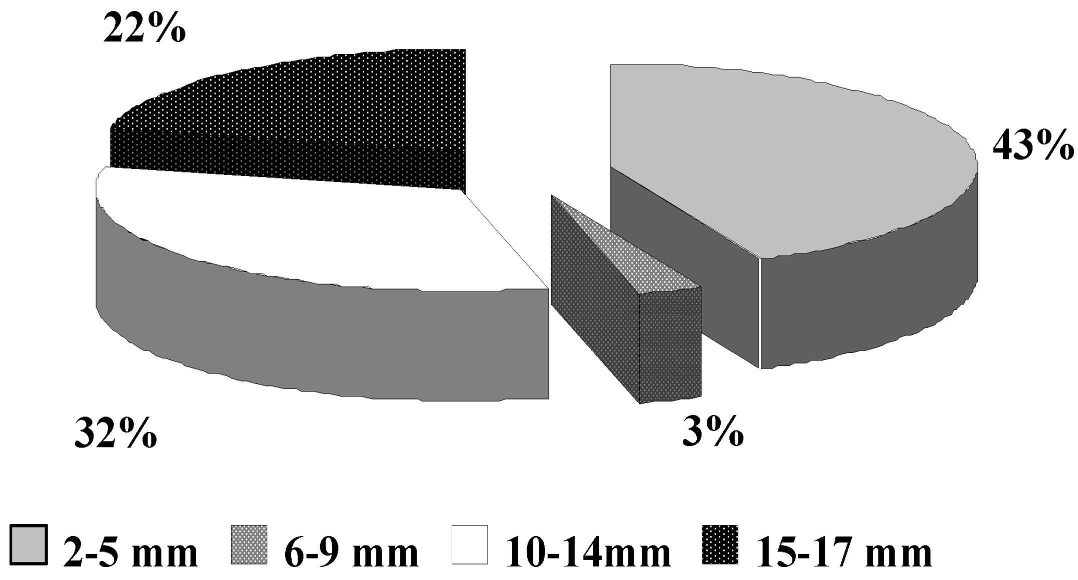

Figure 5. Percentage composition of size class of *Abra segmentum* in Lesina lagoon- October 2008

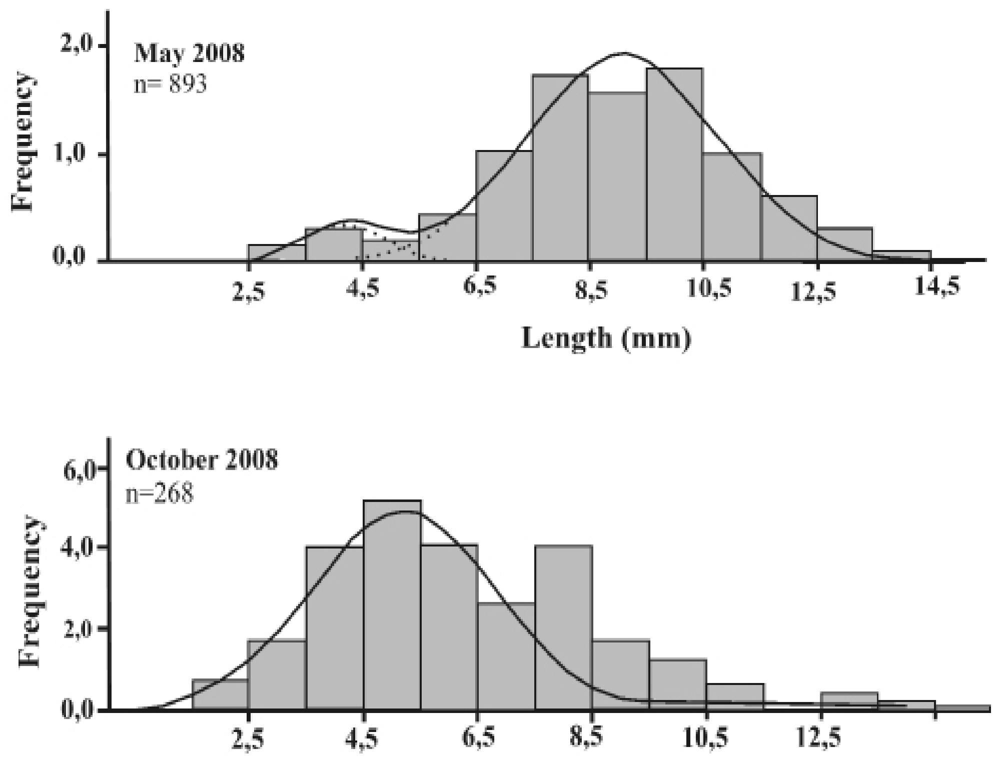

Figure 6. Length- frequencies distribution of *Abra segmentum* in the crisis area from specimens collected May and October 2008.

of 18 units contained 893 individuals, 50% of which ranged within the 6-9 mm size (Figure 7). In October, three months after the dystrophic crisis, the presence of *A. segmentum* in the affected area appeared greatly reduced. The sub-sample comprised only 268 individuals, 43% of which ranged within the 6-9 mm size (Figure 8).

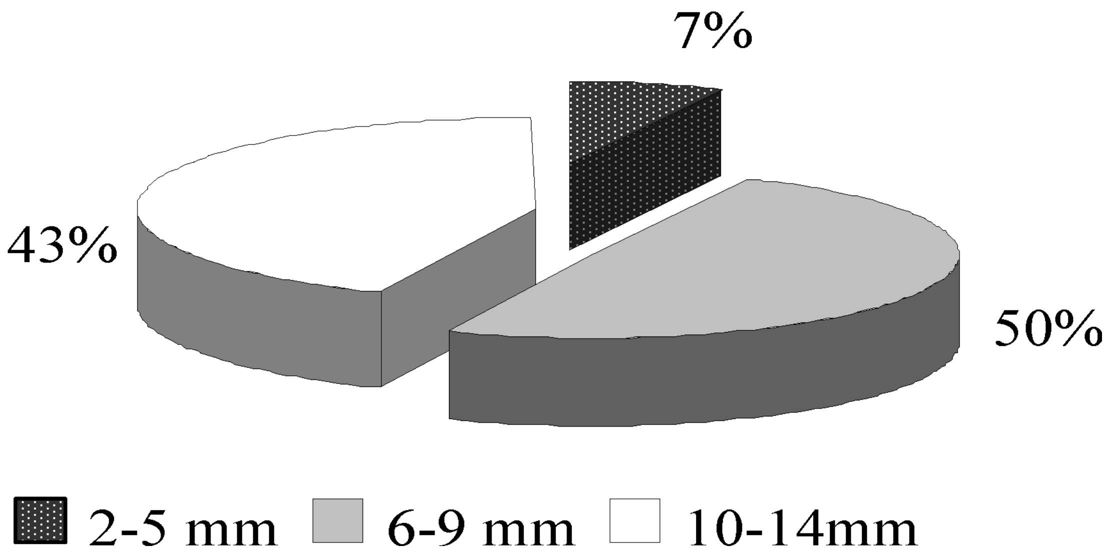

Figure 7. Percentage composition of size class of *Abra segmentum* in the crisis area- May 2008.

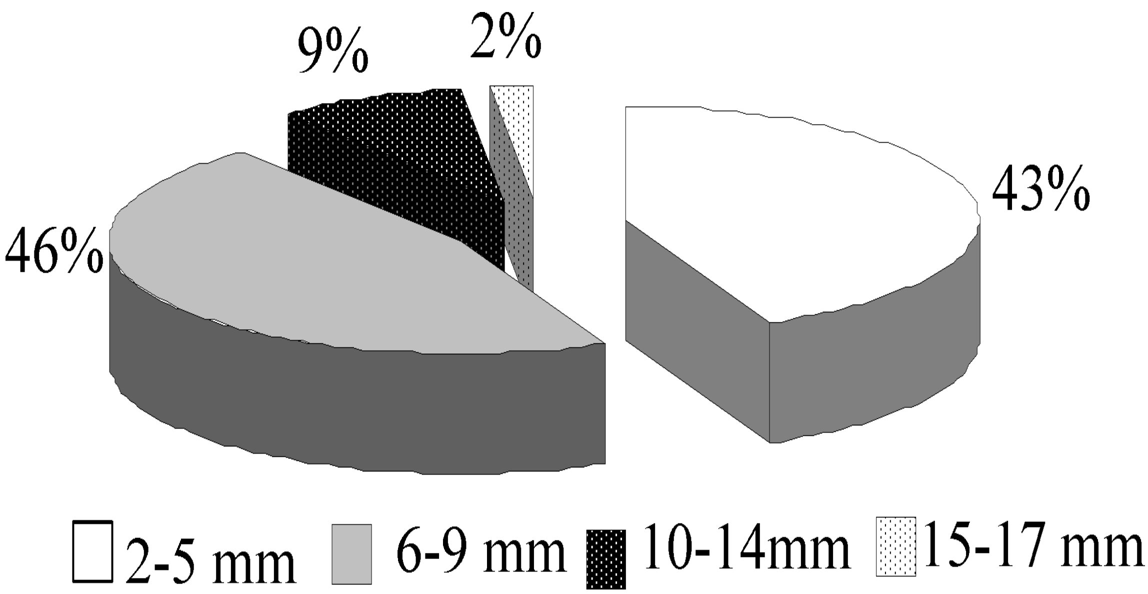

Figure 8. Percentage composition of size class of *Abra segmentum* in the crisis area- October 2008.

Spatial distribution

In May, *A. segmentum* presented an uninterrupted spatial distribution over the entire lagoon with an increasing density from east to west. The mean density was 1466.67 ±1574.76 ind/m^2 with 86% surface coverage. In October there was a diminution in numbers and the distribution was not uniform. The southwest area still conserved the highest density but the central portion of the lagoon presented only rarefied patches. Mean density was 664.92±1113.06 ind/m^2 with a coverage of 74% (Figure 9a, b). In the area affected by the dystrophic crisis at the end of June, covered by a sub-sample of 18 units/stations, *A. segmentum* in May presented a high density (2204.94 ±2077.38 ind/m^2) with a coverage of 100%. In October only two stations out of 18 hold specimens. The mean density dropped to 661.73±1635.19 ind/m^2 with only a coverage of 33% (Figure 9c, d).

Statistical analysis

Differences between stations are shown by n-metric MDS applied to the number of size classes in each station and for each sample, considering whole lagoon or the subarea affected from crisis (Figure 10). This analysis did not show strong perturbations on the entire lagoon (Figure 10a, b); in contrast, considering only the area interested by the crisis, *nm*MDS showed a clear difference of size classes between the two observation period (Figure 10c, d). The ordination diagrams of the May sample from the sub-area (18 stations/s.u.) showed closely grouped stations and a value of stress <0.1, while the analysis of the data in October revealed the effect of the dystrophic crisis at the end of June 2008, with scattering of sites and a value of stress > 0.25.

Discussion and Conclusions

In Lesina lagoon, *A. segmentum* is a common and more abundant species, characterized by high population density (Specchiulli *et al.*). The values of abundance observed in spring in Lesina lagoon are similar to those reported in other Mediterranean areas, as

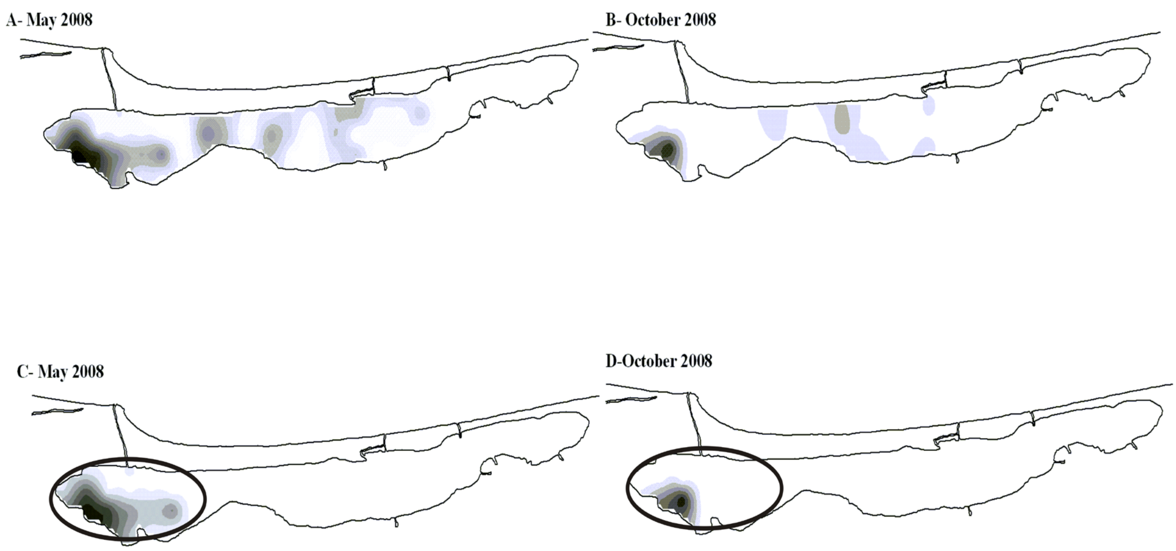

Figure 9. Spatial distribution of *Abra segmentum* over the entire lagoon in a) May 2008, b) October 2008 and in the crisis area (circle) in c) May 2008 and d) October 2008 area (in circle).

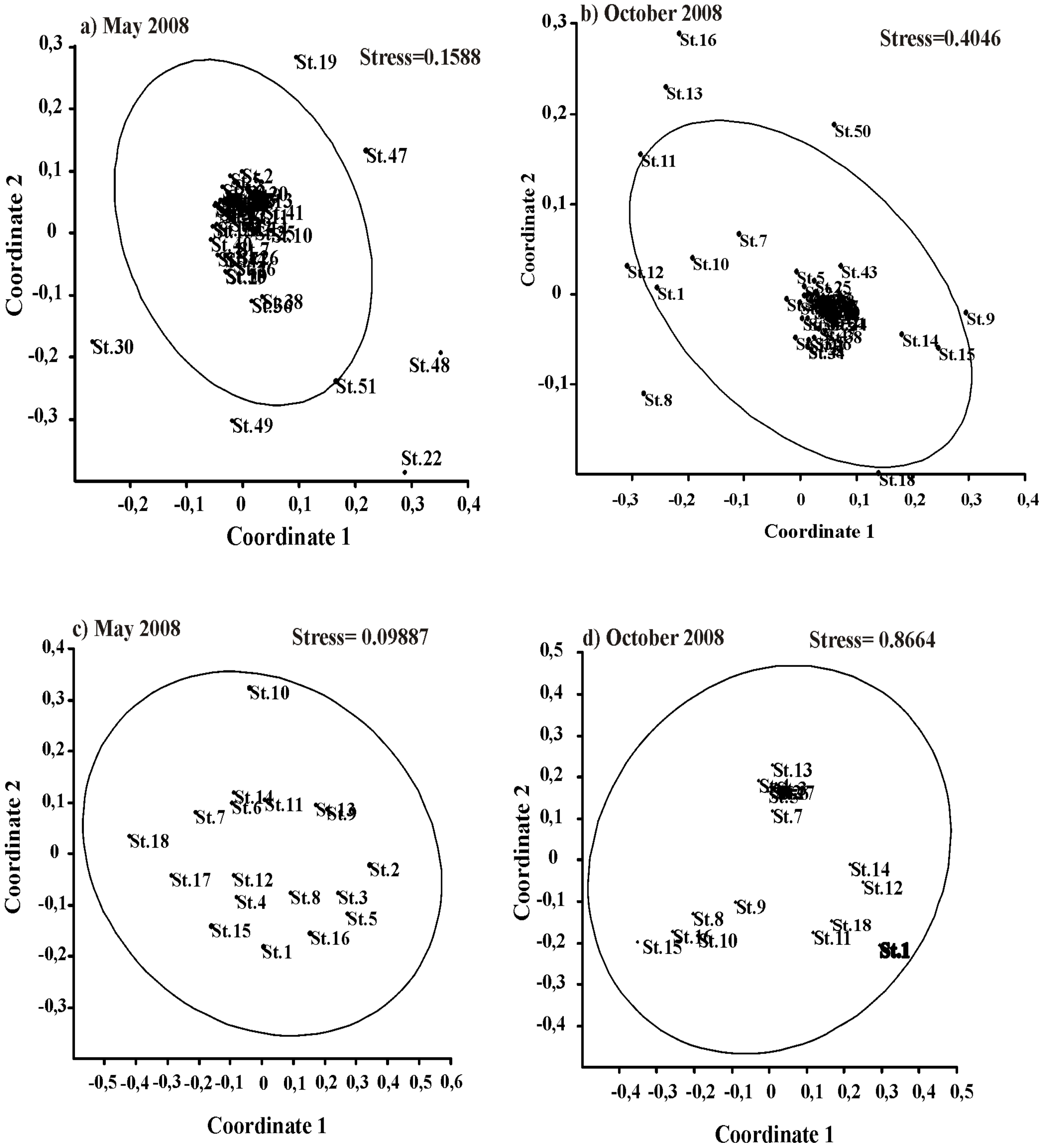

Figure 10. Ordination diagrams performed on the number of size classes over the entire lagoon a) May 2008, b) October 2008 and in the crisis area for c) May 2008 and d) October 2008.

Evros Delta (1632 ind/m^2) (Kevrekidis and Koukouras, 1992) and Tsopeli lagoon (1041 ind/m^2) (Reizopoulou and Nicolaidou, 2007) in the same sampling period, but lower those observed in an other Mediterranean lagoon-Vivari (4887 ind/m^2) (Reizopoulou and Nicolaidou, 2007). The analysis of population structure showed that the population in Lesina lagoon consisted of two cohorts. This result is in according to that obtained in Tsopeli lagoon (Reizopoulou and Nicolaidou, 2007) and Evros Delta (Kevrekidis and Koukouras, 1992), but opposed to that found in Vivari lagoon by Reizopoulou and Nicolaidou (2007) and in Ria Formosa by Sprung (1994) who pointed out that the population of *A. segmentum* consisted of one cohort. The results obtained in this study highlight the rapidity of re-colonisation of *A. segmentum* after the strong disturbance caused by the insurgence of dystrophic crisis. The renewal time of this species is shown by the appearance of juveniles (2-5 mm) in the area interested by crisis (October). In detail, the length/frequencies distribution in May showed a limited generation of juveniles (6%) compared to that of the adults (50%) over the entire surface of the lagoon. Distribution was ubiquitous with 86% of the stations showing the presence of the bivalve. Most (52%) of the population was concentrated in the southwest portion of the lagoon. In October the situation changed. The younger generation received more recruits in the meantime and accounted for 43% of the population and the older generation dropped to 32%. The spatial distribution still presented a higher concentration in the southwest part of the lagoon, but it was generally contracted into widely-spaced patches. The dynamics of the population is particularly clear when considering the area affected by the dystrophic crisis. In May the population was structured as in the rest of the lagoon, but in October there was a marked difference. The length/frequencies distribution did not show the usual two partially overlapping peaks, but the two generations were wiped out at the end of June and a completely new set of juveniles re-colonised the area, probably generated by the animals outside the stricken area. These results suggest that recruitment occurred probably earlier in September, as the most frequent size class in the sub-sample of October was 5 mm. The insurgence of a dystrophic crisis in Lesina lagoon allowed to clearly observe the resilience of *A. segmentum* to environmental stress, confirming it as an *r* strategy species, as defined by Pianka (1970), with small size, brief life cycle and great capacity of recovery after environmental crises (Table 2).

The benthic macrofauna in Lesina lagoon has been sampled since 1993 (Breber *et al*. 2007)

Table 2 - Strategy (*r* and *k*) adopted by species according to Pianka (1970) based on ecological characteristics

Characteristics of selection r and K		
Characteristic	***Selection r***	***Selection K***
environment	unpredictable	predictable
size of population	change over time	costant over time
competition	low	great
selection criterion	quick development	slow development
	precocious reproduction	slow reproduction
	small size	large size
	numerous individuals	few individuals
expectancy of life	short (<1 year)	long (>1 year)
step of succession	precocious	last
carry out	productivity	efficiency

and the presence of *A. segmentum* through time and space is uninterrupted, showing the highest number of individuals, the greatest biomass and spatially the most widespread among the species in the samples. The analysis of the population structure over 15 years shows that the life span of this bivalve hardly exceeds 12 months and reproduction proceeds uninterruptedly from May to September so that the size-frequency curves do not reveal clear-cut intervals between generations. The generations are thus staggered and the last born in the year serve as breeders in the spring of the next and then die. In occasion of the dystrophic crisis an area was wiped clean of all preceding generations so that we were able for the first time to separate the generations.

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