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Population structure of *Cerastoderma glaucum* and *Abra ovata* in Vouliagmeni Lagoon (Attiki)

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Two species of bivalves, *Cerastoderma glaucum* and *Abra ovata*, typical inhabitants of brackish waters, were found in Vouliagmeni Lagoon. Seasonal qualitative and quantitative samples were extracted from the different types of the substratum during 1997–1998. Overall, 800 individuals of *C. glaucum* and 2700 individuals of *A. ovata* were collected and measured and their population structure studied.

INTRODUCTION

Two bivalve species, *Cerastoderma glaucum* and *Abra ovata*, recorded in Vouliagmeni Lagoon (surface area 4000 m^2, Attiki, Greece). Both these species are typical inhabitants of brackish waters (Barnes, 1980). Bivalves can be useful indicators of the environmental condition of brackish water lagoons (Breber, 1996). In the present study, the population structure of both species was studied and the results discussed in relation to the tourist activity in the study area.

MATERIALS AND METHODS

Seasonal samples (07/1997, 10/1997, 01/1998 and 04/1998) were collected with SCUBA diving at different sites throughout the lagoon during 1997–1998. The maximum depth of the lagoon is 13 m. Samples were collected from four different lagoon habitats (see Table 1). Samples from the soft substrate were taken with a corer ($20\times15\times10$ cm$=3.180$ cm^3). Nine and three random samples were taken from the upper (0.5 m) and lower parts (5–7 m) of the infralittoral zone, respectively. Samples from the hard substrate (4–8 m) were collected with a 20×20 cm^2 sampler. Six random samples were taken seasonally from the hard substrate zone, which is restricted to the north side of the lagoon. In addition, three semi-quantitative random samples of seaweeds were collected from the deeper parts of the lagoon (3–5 m). Each sample filled a 5-l container. All samples were preserved in a 10% formalin solution.

Samples were sieved through a 1-mm sieving net. Consequently dead individuals were separated from living ones, counted and all living individuals were measured using an electronic Vernier calliper (Mitutoyo, UK). The following morphological parameters were measured: (a) shell length (L, in mm); (b) shell height (H, in mm); and (c) total wet formalin weight (W, in g).

The relationship between L and H was described using linear regression whereas that between W and L using the exponential regression (i.e. $W=aL^b$) after logarithmic transformation ($LogW=Loga+bLogL$). Length–frequency distributions were constructed, using a size-class step and analysed using Bhattacharya's method. Mean abundance by habitat type was compared using one-way analysis of variance (ANOVA) after log transformation.

RESULTS AND DISCUSSION

Overall, 800 individuals of *Cerastoderma glaucum* were collected and measured. This species was found on all substrate types with the exception of LPI (Table 1). Shell length ranged between 3.00 and 30.78 mm. The relationships between L and H and W and L were: $H=-0.034+0.7995L$ ($r^2=0.99$, N=628, $P<0.05$) and $LogW=-3.996+3.244LogL$ ($r^2=0.99$, N=628, $P<0.05$). Although abundance was generally higher in winter, seasonal differences in abundance were not statistically significant (ANOVA, for all cases, $P>0.17$) (Table 1). The size–frequency histograms clearly revealed that recruitment takes place mainly in autumn (Figure 1). Few recruits were also recorded in winter (Figure 1), a fact indicating a rather prolonged reproductive activity (i.e. from spring to early summer). Separation of length frequencies into normal distribution components was possible only for the winter and spring samples, with two normal components identified for each season (Figure 1). The population almost disappeared in summer when only four individuals were caught (Table 1).

Overall, 2700 individuals of *Abra ovata* were caught. Its distribution was limited to the UPI. A small number of individuals collected from the soft substrate of the sublittoral zone were dead. Although abundance was higher in winter (Table 2), a fact that could be attributed to the limited number of bathers during that period, seasonal differences in abundance were not significant (ANOVA, $F=1.54$, $P=0.18$). Shell length ranged between 2.00 and 8.86 mm. The size–frequency histograms showed that recruitment was generally observed throughout the year (Figure 2), a fact suggesting that reproductive activity is also continuous throughout the year. Separation of length frequencies into normal distribution components was possible only for the summer and spring samples, with one normal component identified for each season (Figure 2), suggesting longevity of one year. The absence of individuals with shell lengths larger than 8 mm in summer could be attributed mainly to natural mortality. The relationships between L and H and L and W were: $H=-0.2906+0.7833L$ ($r^2=0.8817$, N=1835, $P<0.05$) and $LogW=-3.7953+2.9639\ LogL$ ($r^2=0.8691$, N=1835, $P<0.05$).

Cerastoderma glaucum and *A. ovata* both tolerate a wide range of salinities, ranging between 3 to 61 psu for the

Table 1. *Abundance of* Cerastoderma glaucum *in different habitats and seasons.*

Season	Summer 1997				Autumn 1997				Winter 1998				Spring 1998			
Habitat	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range	N	Mean	SE	Range	N
UPI				1	17.7	8.9	0–66	159	13.5	5.8	0–56	122	3.11	1.3	0–10	28
LPI	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
HS				3	27.7	25.5	0–155	166	9.7	3.4	1–23	58	1	0.7	0–4	6
SW				—	171.7	112	0–383	515	69.3	27.7	20–96	208	40	28.1	8–96	120

SE, standard error; N, number of individuals per 3180 cm^3 for the UPI, per 400 cm^2 for the HS and per 5 l for the SW. UPI, upper part of the infralittoral zone; LPI, lower part of the infralittoral zone; HS, hard substrate from infralittoral zone; SW, seaweeds.

Table 2. *Abundance of* Abra ovata, *in the upper part of the infralittoral zone in different seasons.*

Season	Mean	SE	Range	N
Summer 1997	53.78	8.2	(15–103)	484
Autumn 1997	55.44	15.48	(0–134)	499
Winter 1998	122.3	42.63	(12–410)	1101
Spring 1998	32.9	9.9	(2–97)	296

SE, standard error; N, number of individuals per 3180 cm^3.

former and between 3 to 41 psu for the latter (Barnes, 1980; Nicolaidou & Kastaki-Apostolapoulou, 1988; Kevrekidis & Koukouras, 1992). In Vouliagmeni Lagoon, the salinity ranged between 17 and 18 psu (Chintiroglou et al., 2000).

The life span of *C. glaucum* in the study area was ~1 y, with recruits appearing mainly in autumn, and the maximum observed length was 30.78 mm, which are both much smaller than those reported from other northern

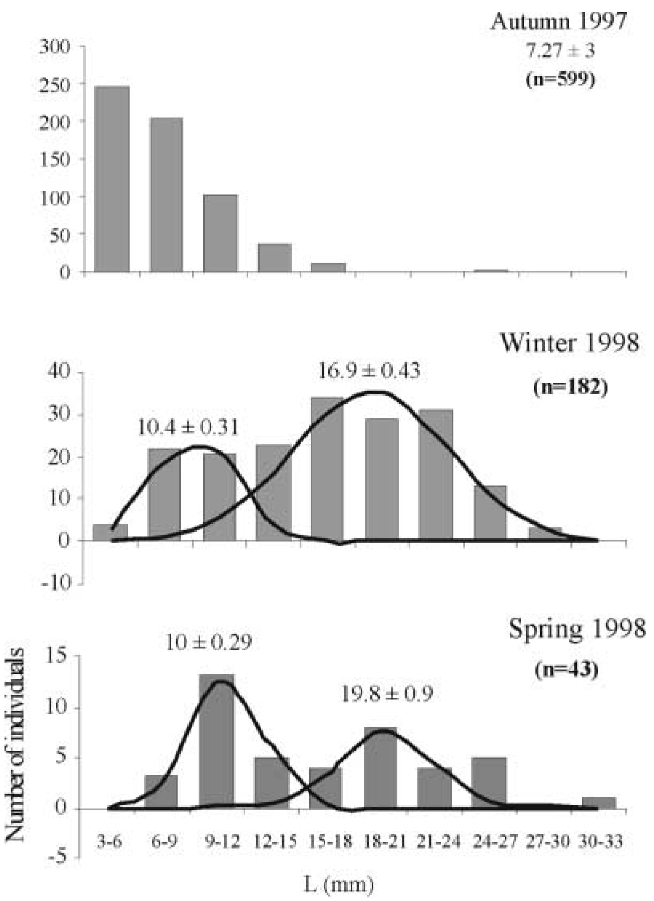

Figure 1. Size–frequency histograms for *Cerastoderma glaucum*, with superimposed normal composition components (N, number of individuals, mean ± standard deviation).

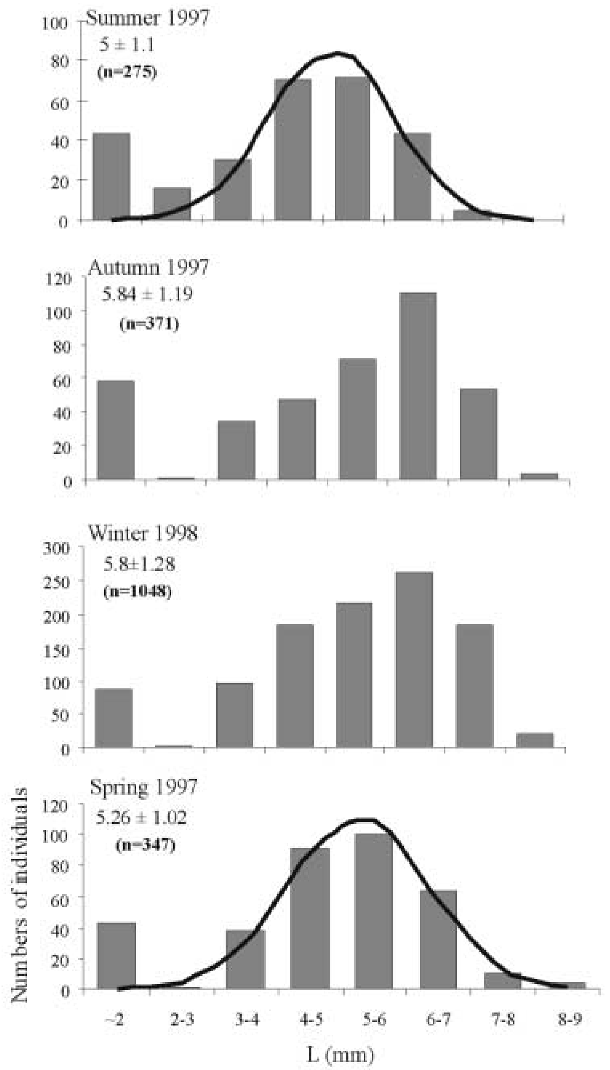

Figure 2. Size–frequency histograms for *Abra ovata*, with superimposed normal composition components (N, number of individuals, mean ± standard deviation).

areas of its distribution (e.g. 50 cm and 7 y in Irish waters: Boyden, 1972).

Available data show that populations of *A. ovata* are characterized by a long settlement period with differences being closely related to the prevailing water temperature and sufficient food resources, salinity and oxygen concentration (Nicolaidou & Kostaki-Apostolopoulou, 1988; Kevrekidis & Koukouras, 1992). In Vouliagmeni Lagoon, recruitment of *A. ovata* took place all year round. In contrast, in Mazoma Lagoon it exhibits two maxima, one in June and another one in September (Nicolaidou & Kostaki-Apostolopoulou, 1988) and in Evros Delta (north-eastern Aegean Sea) it takes place during October–January (Kevrekidis & Koukouras, 1992). Maximum shell length in Vouliagmeni Lagoon was about 9 mm, much smaller than that in the Evros Delta (i.e. 20 mm: Kevrekidis & Koukouras, 1992), one of the most eutrophic areas of the Greek Seas being also characterized by lower prevailing water temperature (Stergiou et al., 1997) when compared to the study area.

Differences in the maximum observed shell sizes of both species in the study area when compared to other areas of their distribution could be attributed to the lower trophic conditions and higher temperatures prevailing in Vouliagmeni Lagoon. Temperature and food potential are the most important factors affecting phenotypic differences in growth patterns and maximum sizes in a variety of marine organisms (e.g. Stergiou et al., 1997).

Lastly, human interventions in Vouliagmeni Lagoon seem to affect the population structure of *C. glaucum* especially during summer, when bathers are numerous. Significant amounts of seaweed are removed each year for tourist purposes (Chintiroglou et al., 2000). Such a removal might seriously affect the population structure of *C. glaucum*, as seaweeds form the main area for the larval settlement. On the other hand, the extraction of seaweeds might prevent high sedimentation of organic material, which results in anoxic sediment layers, a fact that generally complicates the overall assessment of such a removal. Thus it becomes apparent that a rational administrative policy is essential for the management of the Vouliagmeni Lagoon.

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