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Abstract

Monthly collections were made for one year (March 2001 to February 2002) in Mar Piccolo of Taranto (Ionian sea, Italy), in order to establish the seasonal fluctuations of a population of Gammarus aequicauda (Crustacea, Amphipoda).

Variations in the population structure, sex ratio and fecundity were studied. The population comprised all stages of the life cycle all year round, thus showing continuous reproduction. Size differences between males and females occurred throughout the year with males being larger than females. The recruitment of juveniles into the population occurred particularly in autumn-winter. Females consistently predominated in numbers over males during winter months. Female cephalic length was positively correlated with eggs number.

Keywords: Estuarine population, *Gammarus aequicauda*, amphipod, monthly fluctuation.

Introduction

Gammarus aequicauda (Martynov, 1931), (Crustacea, Amphipoda), is an euryhaline and euryvalent species very common in warm temperate waters. It is a characteristic inhabitant of lagoon systems and shallow coastal waters, down to a depth of ca 20 m, usually in localities with freshwater influence (lagoons, river mouths) under stones or among algae. Considerable ecological information on this species has been given by CHASSANY DE CASABIANCA (1979); DIVIACCO (1983); PORCU & TAGLIASACCHI MASALA, (1983), while information about its life cycle is given by BRUN (1975), GREZE (1977), JANSSEN *et al.* (1979) and KEVREKIDIS & KOUKOURAS (1988/89; 1989).

This species plays a considerable role in the structure of benthic communities and represents an important component in marine benthic food webs. (KEVREKIDIS & KOUKOURAS, 1989).

The aim of this study is to investigate the monthly fluctuations in an estuarine population of *Gammarus aequicauda*, in Mar Piccolo in Taranto, in order to provide some information on their reproduction and biology.

Materials and Methods

Study area

The sampling area is the Second Inlet in Mar Piccolo in Taranto (Fig. 1). Mar Piccolo is an important zoogeographic area from ecological and economical aspects: it represents a closed coastal marine ecosystem characterized by restricted circulation. It is made up of two basins: the First and the Second Inlets, with a maximum depth of 13 and 10 m respectively. Water exchange occurs with Mar Grande through two channels, and the water flow is subject to tidal effect.

Sample analysis

Monthly samples of the species were collected during one year: from March 2001 to February 2002.

Amphipods were obtained by using a square metal box (25 X 25 cm) taking 3 random samples. The samples were sieved in a 1 mm mesh and the animals were fixed with 4% formalin.

Temperature, salinity, pH and oxygen were measured using a multiparametric sampler "ME CTD 1500".

Animals were counted and measured along the mid-dorsal line, from the tip of the rostrum to the tip of the telson, under a stereomicroscope fitted with a micrometer eyepiece. Regarding sex distinction, the amphipods were classified as juveniles, females or males. Females were distinguished by the presence of oostegites and males by the penial papillae. Females were separated into three groups: immature – small and non setose oostegites; mature - with setose oostegites without embryos and gravid females with eggs or juveniles in the brood pouch. Sexual dimorphism is only evident in adult animals and was identified by the size and shape of the gnathopods. Animals less than ≤ 3.1-4 mm long could not be sexed externally and were recorded as juveniles (NAYLOR *et al.*, 1988).

The number of males, females and juveniles, was expressed as a percentage of the total number of individuals.

The embryos of each egg-bearing female were counted and classified in the 4 developmental stages (A, B, C, D) described by JANSSEN *et al.* (1979) for the genus *Gammarus*.

Stage A: the small micromeres divide more rapidly than the macromeres, resulting in a germinal disc, which extends over the surface

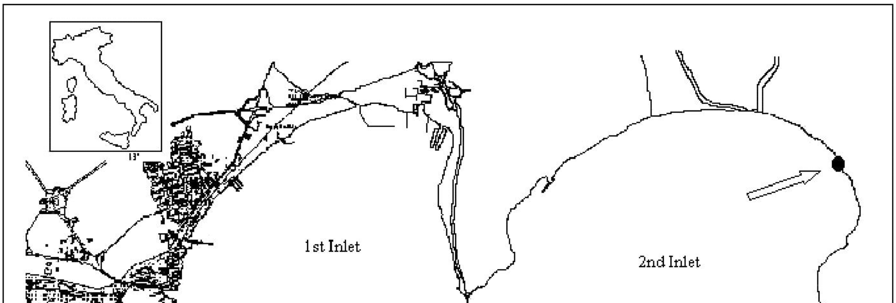

Fig. 1: Geographic location of study area.

of the egg, enclosing the yolk cells, constituing the blastoderm.

Stage B: gastrulation starts from the posterior region of the germinal disc. Ventrally gastrulation proceeds by the proliferation of cells inwardly to form the embryonic mesoderm and endoderm.

Stage C: The differentiation of appendages and embryo organs, the embryo is characterised by its comma-like shape and the dorsal organ is formed.

Stage D: antennae of the cephalothorax developed, appendages are segmented and eye is clearly visible.

Results

A total of 2677 individuals were collected during the period of study. Abundance was remarkably higher in summer than in winter (Fig. 2), with a maximum of 7200 individuals /m^2 in August (warmest month) (Fig.3).

A minimum of 84 individuals/m^2 in November, no males were collected, presumably due to low amphipod number in this sample. This shows that, in spite of the low autumn – winter densities *G. aequicauda* is present throughout the year in Mar Piccolo. The seasonal change in the density of *G. aequicauda* was significantly linked with temperature fluctuations ($r= 0.622$ $p<0.02$) and pH ($r=0.593$ $p<0.05$).

No relationship was found with salinity and oxygen.

Size frequency histograms for males, females and juveniles of *Gammarus aequicauda* are shown in Fig.4, it can be seen that in spring the population consists of adult

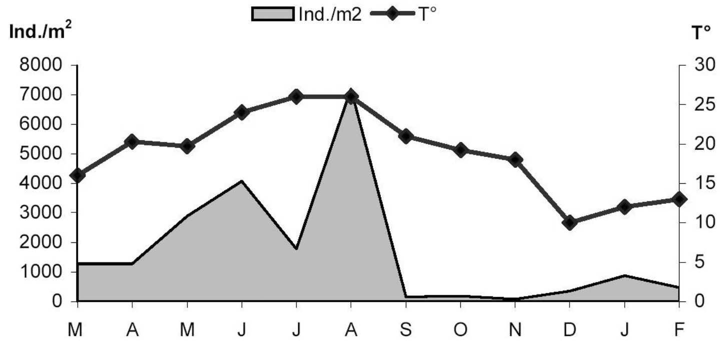

Fig. 2: Monthly changes in temperature and in *Gammarus aequicauda* density in Mar Piccolo of Taranto.

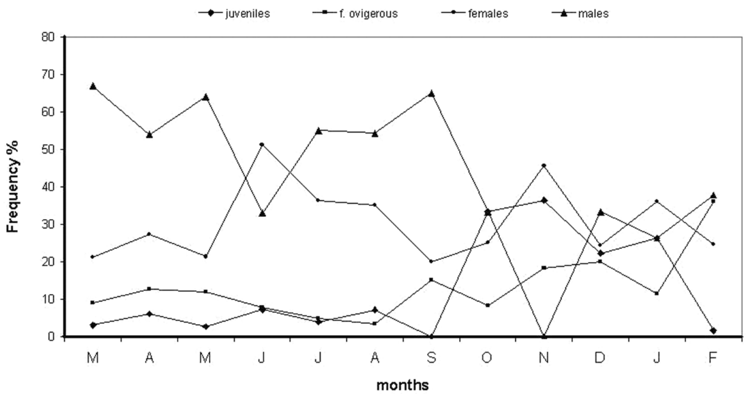

Fig. 3: Seasonal changes in the frequency of total number of individuals.

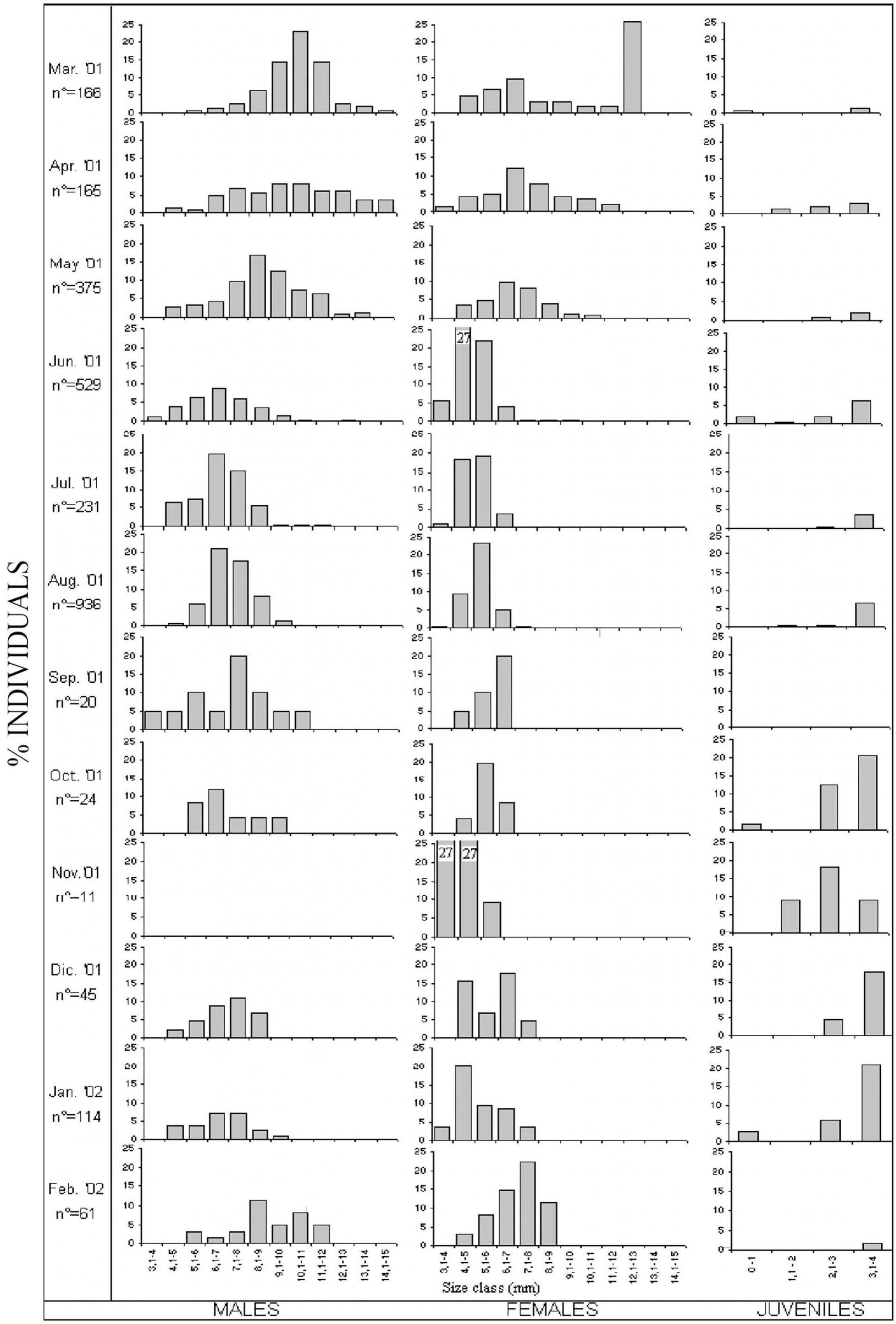

Fig. 4: Size frequency distributions of the *Gammarus aequicauda* population; n, the number of measured individuals.

individuals and few juveniles. In this period the males and females show their maximum size of 14,1-15 mm and 11,1-12 mm respectively. Size differences between males and females occurred throughout the year, with males being always larger than females.

From June to August most of the last generation seem to die and the population is represented by a number of juveniles and small-sized animals. This population remains relatively constant during early autumn until December being mainly made up of small-sized adults.

Reduction in the minimum size of mature females during summer and autumn months has been recorded frequently in other amphipods species: *Gammarus duebenii* Lilljeborg, 1852 (cf. STEELE & STEELE, 1969), *Bathyporeia pilosa* LINDSTRÖM, 1855 and *B. pelagica* BATE, 1856 (cf. Fish,1975), *Corophium insidiosum* CRAWFORD, 1937 (cf. SHEADER, 1978), although this situation is not universal (NELSON, 1980) but probably due to temperature fluctuations, food availability and predation (SHEADER, 1983), or due to a more rapid development of females at higher summer temperatures leading to a smaller size at maturity at this time of the year (BYNUM, 1978).

A number of juveniles can be seen throughout the year determining a continuous recruitment. It is noticeable that in each month the number of juveniles is too small to account for the adults of the next month. This may be a sampling deficiency, as mentioned by ANGER (1979) for other amphipod.

Ovigerous females only outnumbered non ovigerous females in February. The temporal variation of the sex-ratio (number of males/number of females) is given in Fig. 5. The mean value of the sex-ratio was 1.12 (± 0.1 standard error), however, females were more abundant than males during winter months, and in June.

Figure 6 shows the relationship between number of eggs per female and cephalic length (mm) ($r=0.81$ $p<0.005$). The positive relationship between brood size and female size indicates lower fecundity in summer and early autumn because the mean size of mature females was smaller in these seasons (Fig.7).

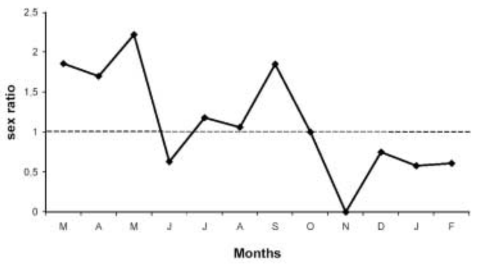

Fig. 5: Monthly variation in the sex ratio of *Gammarus aequicauda*.

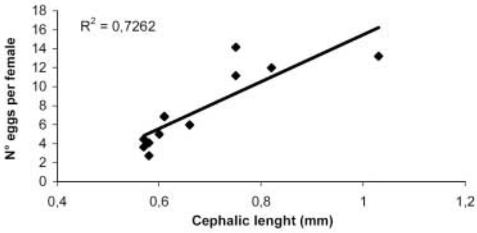

Fig. 6: Relationship between mean female cephalic lenght (mm) and mean number of eggs.

Table 1 shows the mean brood sizes of the embryonic stages A – D of *Gammarus aequicauda*, collected in all monthly samples. The development of eggs in the marsupium of each female was generally synchronous. There was a slight decrease in the brood sizes in stage D compared to the brood sizes in stage A, with an embryo number of 29.7% lower. This ratio is similar in several Amphipoda and ranges between 20-30% (MOORE, 1981).

Discussion

Temporal change in the density, with a maximum in summer and a minimum in autumn – winter was observed in a population of *Gammarus aequicauda* in Mar Piccolo in Taranto. In this species, providing that temperature is not a limiting factor since it is a well known euryvalent species, these fluctuations would be linked with the algal

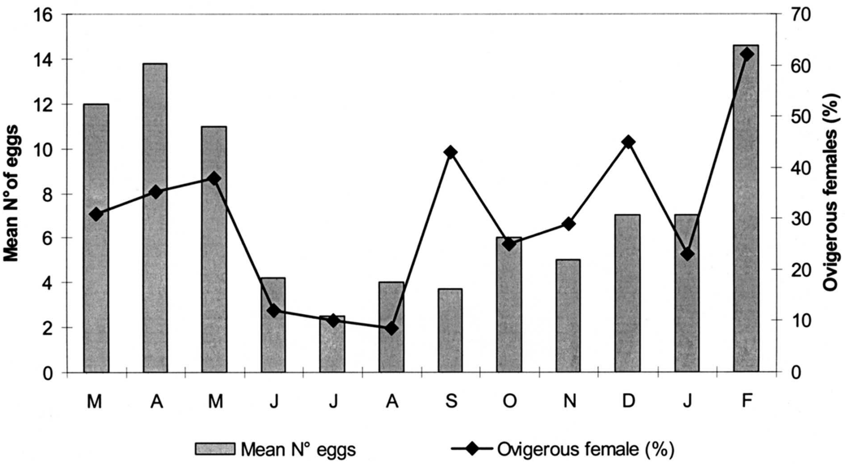

Fig. 7: Monthly variation in the mean number of eggs per female.

covering, because they protect it against predation and it can find food and shelter available for reproducers (KEVREKIDIS & KOUKOURAS, 1989; COSTA *et al.*, 1999).

Many studies have demonstrated a positive correlation between the abundance of amphipods and macroalgae inhabiting the same habitat (STEELE & STEELE, 1975; VASSALO *et al.*, 1980).

Moreover, positive correlation between density, temperature and pH were found, but no relationship with salinity and oxygen.

Gammarus aequicauda seems to have an annual life cycle, although limited recruitment takes place throughout the year. It is noticeable that from March to September the number of juveniles is too small to account for adults of the next months. An increase in juveniles number occurs in autumn – winter but it is not implying the recruitment because there are very few adults found.

The absence of recruitment by juveniles maybe due to a sampling deficiency, as mentioned by ANGER (1979) for other small-sized amphipod species. Furthermore, it is possible that, the decrease in the adult population in autumn- winter months maybe due to some migration of adults between different habitat types related to the breeding periods (KARAKIRI & NICOLAIDOU, 1987; KOLDING, 1981).

Table 1
Embryonic stages of *Gammarus aequicauda*

Embryonic stage	Mean brood size ± sd
A	8,34 ± 6,94
B	9 ± 6,76
C	8 ± 1,41
D	5,86 ± 4,45

The population density was affected by its life cycle, although the predation by fish and large invertebrates is a factor controlling the amphipod population structure which can regulate the seasonal pattern of their abundance (VAN DOLAH, 1978; KARAKIRI *et al.*,1987; WILSON *et al.*, 1996).

The sex ratio varied considerably over the year, exhibiting a preponderance of the females during winter months. KNEIB (1997) suggest that temporal variations in the sex ratio in *Uhlorchestia spartinophila* populations could be influenced by differential mortality caused by seasonal changes in quality or availability of food. Differences in sex proportion have been frequently observed among different population in other species of the genus *Gammarus*. KEVREKIDIS *et al.*, (1988/89) who observed a dominance of males in *Gammarus* *aequicauda*, also found that the females died earlier than the males, directly affecting the sex ratio. Differential rates of growth, maturation, longevity or predation can all result in skewed sex ratios (NAIR & ANGER, 1979; BEARE *et al.*, 1996). WATT (1994) showed that photoperiod influence the sex ratio of *Gammarus duebeni*, with preponderance of males when exposed to long days, and preponderance of females on exposure to short days. Some differences observed may be an artefact caused by different habits of the sexes and various sampling methods (BRUN, 1975). According to the above-mentioned causes, it is possible that our results could be explained by some of these hypotheses, but further studies will have to be carried out.

Temporal changes in the percentage of the ovigerous females indicates that the population was sexually active throughout the year: this is observed also in other populations of *Gammarus aequicauda*, studied by BRUN (1975), GREZE (1977), JANSSEN *et al.* (1979), PORCU & TAGLIASACCHI MASALA (1983), KEVREKIDIS & KOUKOURAS (1988/89).

The size of the brood was directly related to the cephalic length of the female. *Gammarus aequicauda* females become ovigerous when they reach a size of about 5mm, their marsupia contain, however, more than 20 eggs only when females exceed 8mm. Embryo numbers was lower in stage D than in stage A, this result was observed in several amphipoda and in other Peracarida (MOORE, 1981).

SHEADER (1983) observed that the loss of eggs from the marsupium prior to completion of development, in *Gammarus duebeni* may be due to two mechanisms.

The first was the result of seasonally occurring environmental extremes, the activity of the female will be considerably reduced at low temperatures, increasing the chance of egg loss through the posterior opening of the marsupium during period of slow pleopod beat or pleopod arrest. The second involved partial ingestion of the brood by the female. Our observations do not offer conclusive evidence in support of any of the possible explanations.

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