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Zooplankton composition in Lake Varano (Adriatic Sea coast, Italy)

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Abstract

The zooplankton composition of Lake Varano has been studied from June 2007 to May 2008 considering three sampling stations (western, central, eastern). A total of 55 zooplankton categories were recognised, with medusae *Aurelia aurita* as the main macroscopic species; 43 of them occurred in less than 50% of the 71 samples collected, highlighting the seasonal aspect of the community. The remaining 12 categories, present in more than 50% of samples, were numerically dominated by the copepod 'Non Indigenous Species' *Acartia tonsa* (reported here for the first time in the lake), which occurred throughout the year. Maximal abundance of zooplankton was recorded in the eastern sampling station, while the lowest values were recorded in the central one. The statistical analysis of data allowed us to establish a not sharp separation of the three sampling stations, apart from isolated dates. The present zooplankton assemblage showed that about 40% of its components differed from those recorded in a study of 18 years before. This last comparison is not easily referable to the ongoing climate warming (the dominant species are of cold temperate origin) and analysis of uninterrupted time series could be useful to understand the underlying reasons.

Keywords: *Lake Varano*, *zooplankton variability*, Acartia tonsa, Aurelia aurita, *Adriatic sea*

Introduction

Biological communities of coastal brackish waters are affected by internal and irregular variations, either in space or time (Amanieu & Lasserre 1982; Elliot & Quintino 2007). Zooplankton communities of brackish water habitats along the Mediterranean coasts have been the object of extensive studies, and have been depicted as characterised by seasonally abundant populations of calanoid copepods and meroplankton (Colombo et al. 1984; Belmonte & Bianchi 1992; Gaudy et al. 1995; Campolmi 1998; Calbet et al. 2001; Isinibilir et al. 2008). In general, the biomass peaks one or more times during the warmest months of the spring to autumn period, mainly due to individuals of small-sized species (Calbet et al. 2001; Lam-Hoai & Rougier 2001).

Severely adverse conditions for benthos are common in such environments during the summer, when, also due to increase in temperature, dystrophic crises possibly occur, leading to oxygen depletion on the bottom (Ceccherelli et al. 1987). On the contrary, calanoids spread in the water column during the summer period, representing up to 98% of meso-zooplankters, with thousands of specimens of just one species per cubic metre. In many cases, such species belong to the family Acartiidae, whose populations are known to suffer during winter, a period commonly passed as resting eggs (see Engel 2005 for a list of coastal calanoids producing resting eggs).

A study carried out in 1989–90 on five different coastal lakes of the Apulia region (south east Italy) showed that the Acartiidae of Lake Varano (*Acartia clausi*, *A. margalefi* and *Paracartia latisetosa*) were different from those of the adjacent Lake Lesina (*A. margalefi*), suggesting that the two systems should not be considered as similar (Quarta et al. 1992).

The recent arrival of *Acartia tonsa* in the Mediterranean Sea (Belmonte & Potenza 2001) and in the Lake Lesina (Sei & Ferrari 2006) suggests this could lead to an alteration of equilibrium in zooplankton communities of those confined environments, and stimulated a control of the situation in Lake Varano. In addition, the report of regularly

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occurring outcrops of *Aurelia aurita* in Lake Varano (Manini et al. 2003) suggested a possible jellyfish bias (DeMott 1989; Gliwicz & Pijanowska, 1989) on the zooplankton, as recently claimed also in other confined coastal lakes (Lucas et al. 1997; Benović et al. 2000).

Lake Varano is an oligo-mesotrophic ecosystem of the Italian Adriatic coast, and a rich mussel fishery farm with a rich annual production of 6000–8000 tons of *Mytilus gallorovincialis* (Breber & Scirocco 1998) is present. Such a resource has been recently reduced within the lake, while fishing has recently become the most important activity (Manini et al. 2003).

The site is a semi-enclosed coastal lake, with a total area of about 65 km^2, separated from the Adriatic Sea by a 10 km long land strip (Figure 1). The depth reaches a maximum of 6 m (medium 3.5 m). The water exchange between the lake and the sea, which is primarily driven by a semi-diurnal tide, is poor due to the presence of only two small artificial canals (Figure 1). It is estimated that the residence time of water is approximately 1.5 years (Specchiulli et al. 2008). According to the climatic station located at the village of Cagnano Varano, winter is the rainiest season, with a precipitation average of 848.9 mm $year^{-1}$. North–northwest winds are very frequent in the area, especially during the winter season, helping seawater injection into the lake. Hydrological investigations on the water balance of the lake (Villani et al. 2000; Spagnoli et al. 2002) estimated a freshwater input of approximately 87,000 m^3 day^{-1} with remarkable organic content mostly deriving from urban and agricultural runoff, fish-farm and zoo-technique activities (Specchiulli et al. 2008).

In a 1971 study, water temperature ranged between 9.0 and 27.0°C, salinity between 18.7 and 20.6 ppt, pH between 7.6 and 8.4 (Blundo et al. 1972). Marolla (1981), who studied the Varano environment in 1975, defined it as never eutrophic.

Human activities affect the ecology of the lake indirectly by altering the entire water catchment area, and directly with extensive aquatic farming and fishing.

The availability of samples collected from the same lake in 1989–90 (from the study of Quarta et al. 1992) allowed us to also compare, at least qualitatively, the zooplankton species composition from two distanced times.

Materials and methods

Temperature, salinity, pH, and photosynthetically active radiation (PAR) of the water column were measured at two levels (50 cm below the water surface and 50 cm above the bottom of the lake) by using a multiparametric probe (HYDROMAR) in three different sampling stations (western, W; central, C; eastern, E) (Figure 1, Table I), always in the morning (10:00–12:00 a.m.).

Zooplankton has been collected monthly with oblique towing (from the bottom to the surface) of a plankton net (25 cm diameter, 75 cm long, and 200 μm mesh), with a flow meter positioned in the centre of its mouth. The small mouth diameter of the net was chosen to reduce the catch of large jellyfishes, which are sometimes abundant. The sampling has been carried out from 2 July (VI) 2007 to 22

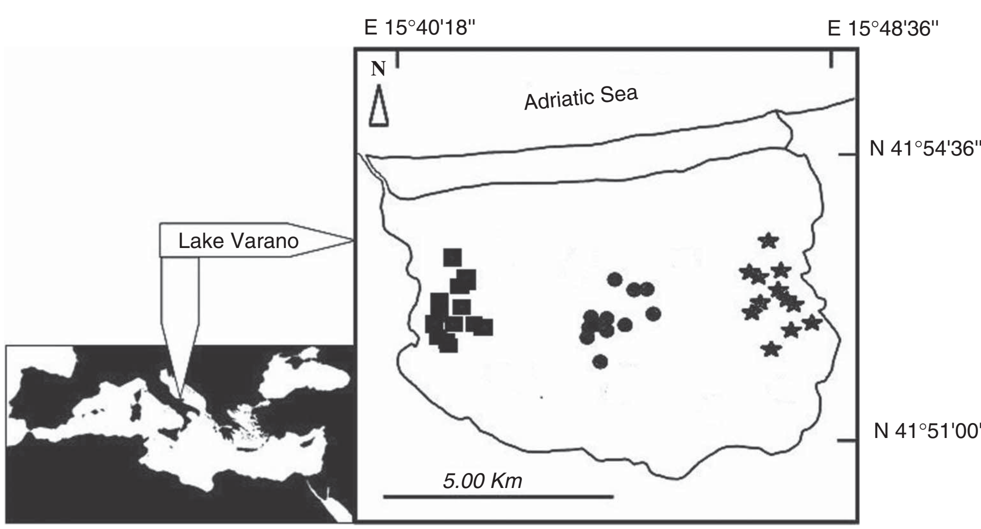

Figure 1. Left, geographic position of Lake Varano on the eastern Italian coast. Right, position of sampling points in the lake, arranged according to three sampling stations: western (squares), central (disks), eastern (stars).

Table I. Details of dates, and filtered water volume in both sample replicates collected in three (W,C,E) stations of Lake Varano.

Date	Station	Filtered water volume (m^3)
02-Jul-07	E	3.94 – 4.89
VI	C	3.19 – 3.19
	W	2.75 – 1.80
31-Jul-07	E	5.75 – 7.21
VII	C	6.29 – 5.09
	W	4.93 – 5.17
03-Sep-07	E	7.83 – 5.25
VIII	C	6.08 – 8.00
	W	7.56 – 7.39
05-Oct-07	E	6.53 – 5.66
IX	C	4.86 – 4.71
	W	5.08 – 4.53
24-Oct-07	E	6.14 – 4.74
X	C	5.18 – 4.49
	W	5.03 – 6.97
19-Nov-07	E	8.34 – 4.75
XI	C	5.28 – 5.17
	W	5.27 – 5.53
21-Dec-07	E	4.39 – 4.08
XII	C	4.81 – 4.44
	W	4.02 – 5.43
28-Jan-08	E	4.09 – 3.87
I	C	2.94 – 3.71
	W	3.66 – 4.02
29-Feb-08	E	4.30 – 4.53
II	C	4.19 – 3.72
	W	3.97 – 3.99
19-Mar-08	E	3.41 – 3.81
III	C	3.56 – 3.93
	W	4.25 – 3.37
25-Apr-08	E	4.65 – 4.13
IV	C	6.86 – 4.19
	W	4.76 – 3.30
22-May-08	E	4.09 – 3.48
V	C	7.58 – 4.03
	W	4.22 – 4.34

May (V) 2008 for a total of 12 dates (indicated with Roman numerals in Table I) in the three sampling stations (see Figure 1), with two replicates for each station to obtain a statistical basis on which to discuss space and time distribution of species. In total, 71 samples were collected (the second replicate of VII 2007, station W, was lost).

Samples were fixed *in situ* with buffered (pH 7.3) formalin at a final concentration of 4%. In the laboratory, organisms were assigned to the lowest possible taxonomical categories after analysis under a compound microscope. Large jellyfishes captured were separated from the sample and counted apart.

In order to verify long-term changes in plankton composition, our samples were qualitatively compared with those collected during the survey of 1989–90 (Quarta et al. 1992). The comparison interested only one station (W) and only 10 months, those being the only available references from the 1989–90 study. Samples of 1989–90 were re-analysed for qualitative comparisons, but quantities were not considered due to the different sampling method adopted in that time (a net with mesh size of 80 μm).

A Spearman's rank correlation coefficient has been obtained from the comparison among the abiotic factors variation and the zooplankton abundance or the species number.

The significance of both temporal and spatial variation of plankton community composition was tested using a two-way crossed analysis of similarities for unreplicated data (ANOSIM2) routine in PRIMER (Plymouth Routines In Multivariate Ecological Research) version 6β R6 (PRIMER-E) (Clarke & Warwick 1994). 'Station' and 'Time' were considered as fixed orthogonal factors. For multivariate analyses, the abundance of each taxonomic category was fourth root transformed, to severely downweight the importance of the dominant species, thus allowing the less abundant, and even the rare species to concur in determining similarity among samples. Stress values were shown for each nonmetric Multi Dimensional Scaling (nMDS) plot to indicate the goodness of representation (Clarke 1993).

A 'one-way' similarity percentages procedure (PRIMER SIMPER routine; Clarke 1993) was used in order to obtain the percentage contribution that each *taxon* provided to Bray–Curtis similarities measures. A cut-off criterion was applied to allow the identification of a subset of species whose cumulative percentage contribution reached 40% of the similarity value.

Results

Abiotic data of the water are shown in Table II.

The water temperature varied between 6.69°C (Station W, surface, XII 2007) and 30.20°C (W, bottom, VII 2007). Generally the bottom waters showed temperatures higher than the surface waters at all the sampling stations, with a maximum difference of 2.5°C between the two layers on the same date (W, I 2008).

The water salinity varied between 21.60 (E, surface, I 2008) and 35.01 (W, bottom, VIII 2007). The bottom always resulted to be saltier than the surface at all the stations, with a maximum difference of 7.40 between the two layers on the same date (W, XI 2007).

pH ranged between 7.93 (E, surface, I 2008) and 8.77 (E, bottom, II 2008). Also in this case, the bottom showed the maximum values.

Table II. Characterisation of Lake Varano (three stations per 12 dates). Each abiotic feature (reported as two values: one for the surface and one for the bottom) is the average of three to five measures obtained by the multiparametric probe HYDROMAR. The biotic features (specimens m^{-3}, and species number) are referred to the zooplankton and represent the average values obtained from two samples (replicates). See the text for details.

	VI 07			VII 07			VIII 07			IX 07			X 07			XI 07		
Parameters	E	C	W	E	C	W	E	C	W	E	C	W	E	C	W	E	C	W
Temperature °C	29.64	29.52	29.36	29.17	28.48	29.04	25.77	25.75	25.41				14.30	14.33	14.01	8.99	9.55	9.76
	28.17	28.63	28.60	29.36	28.75	30.20	25.41	25.51	26.87				13.51	13.67	14.33	9.43	9.58	11.33
Salinity (ppt)	26.72	28.17	28.33	28.91	29.35	29.72	30.61	31.07	30.80				25.72	25.50	28.58	24.25	26.19	25.98
	27.26	29.04	28.32	28.73	29.52	35.01	31.03	30.85	34.93		ND		28.30	29.38	30.50	25.75	26.13	33.38
pH	8.52	8.64	8.65	8.21	8.71	8.71	8.33	8.47	8.47				8.54	8.48	8.59	8.57	8.60	8.03
	8.39	8.27	8.59	8.56	8.68	8.72	8.52	8.14	8.50				8.55	8.55	8.59	8.54	8.56	8.34
PAR (µW cm^{-2})	3407	3394	3387	3222	3170	3381	3351	3393	3280				3291	3280	3362	2808	2929	2965
	2727	2706	2660	2686	2796	2850	2708	2716	2828				2508	2655	2656	1884	2433	2375
Tot. abundance	3724	2175	9492	1796	2568	5693	12151	1669	2019	3812	572	4749	2265	2252	1822	6177	3392	5050
Number species	17	10	16	21	12	21	19	16	14	19	17	19	13	7	8	8	13	11

	XII 07			I 08			II 08			III 08			IV 08			V 08		
PARAMETERS	E	C	W	E	C	W	E	C	W	E	C	W	E	C	W	E	C	W
Temperature °C	6.81	7.28	6.69	10.08	8.86	8.57	12.10	11.86	11.80	14.07	13.89	13.85	17.89	17.72	17.63	21.16	21.18	20.79
	6.87	6.87	8.06	9.36	11.34	11.07	12.51	13.90	13.62	14.65	14.62	14.41	17.65	17.30	.18.90	21.62	22.43	22.04
Salinity (ppt)	23.65	24.18	23.44	21.60	23.46	23.13	21.69	22.11	21.71	22.74	23.10	23.34	22.91	23.98	24.13	22.79	23.79	23.58
	24.90	24.97	25.83	23.57	29.18	26.23	25.54	28.63	24.02	25.02	24.00	23.87	23.41	24.24	28.71	25.27	27.05	29.27
pH	8.37	8.34	8.34	7.93	8.32	8.59	8.42	8.36	8.69	8.68	8.69	8.22	8.54	8.58	8.29	8.61	8.48	8.39
	8.20	8.18	8.23	8.54	8.47	8.86	8.77	8.34	8.72	8.20	8.28	8.12	8.43	8.33	8.72	8.47	8.17	8.42
PAR (µW cm^{-2})	3311	3309	2867	3358	3344	3347	3376	3329	3362	2959	3275	3009	3307	3304	3398	3349	3443	2948
	2414	2691	2334	2671	2717	2747	2711	2860	2904	2672	2722	2547	2538	2458	2844	2760	2879	2516
Tot. abundance	272	27	273	6993	1873	1940	1322	1375	1365	12,725	4520	5141	2946	1834	484	110	62	75
Number species	11	9	12	9	13	10	12	14	11	13	16	18	13	15	16	14	13	12

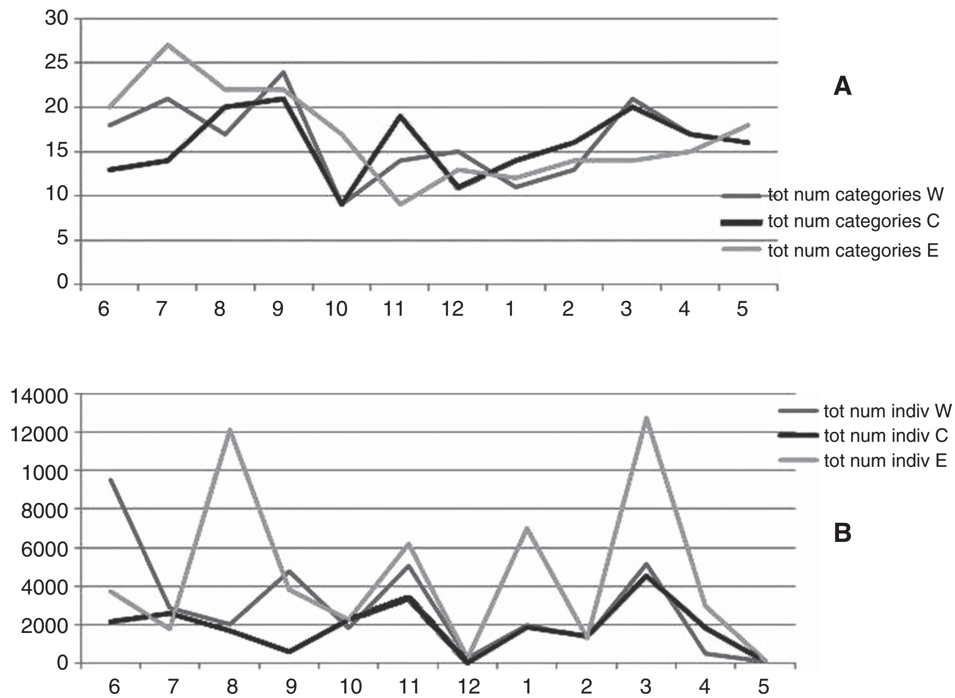

Figure 2. **A**, number of categories found in 12 successive dates (from VI 2007 to V 2008) in the three sampling stations. **B**, variation of specimen number (average on two samples per station) during the period considered (from VI 2007 to V 2008).

PAR ranged between 1884 μW cm^{-2} (E, bottom, XI 2007) and 3407 μW cm^{-2} (E, Surface, VII 2007). The minimum difference between the surface and the bottom data (roughly corresponding to the maximum water transparency, 287 μW cm^{-2}) was recorded in III 2008 at station E.

Among the considered abiotic features of the water, only the temperature was correlated (table of correlations not shown) with zooplankton species richness ($r = 0.604$, $P < 0.001$).

According to the zooplankton composition, a total of 55 categories were recognised in the 71 samples collected during the period VI 2007–V 2008. The species richness of each sample never exceeded 23 categories (average, 13.3 categories per sample) (Figure 2A). The average number of categories per sample was approximately similar at the three stations (W, 13; E, 14; C, 13).

Only 12 categories were present in more than 50% of the samples collected. They were nine categories (larval and juvenile stages) possibly containing more than one species, and three species (adults): *Acartia tonsa* (frequence, 70/71), *Oithona nana* (59/71), and *Acartia clausi* (39/71).

Less frequent categories (those present in < 50% of the samples collected) were considered as strictly seasonal. They were well represented by *Paracartia grani*, larvae of Foronida, ephyrae and medusae of Scyphozoa, and eggs of the anchovy *Engraulis encrasicolus* (Osteichthies).

It has to be underlined that *Acartia tonsa*, the dominant species of the lake, was never reported before for Lake Varano.

During the considered period, the zooplankton abundance averaged 3150 specimens m^{-3} per sample, with a maximum at Station E (III 2008), (12,725 individuals m^{-3}), and two minima at Station C (27 individuals m^{-3}, and 62 individuals m^{-3}, on XII 2007 and V 2008, respectively) (Figure 2 B). Station E showed the maximum average abundance (4522.8 individuals m^{-3}) and Station C the minimum one (1858.8 individuals m^{-3}).

The multivariate analysis carried out on the data obtained from replicated samples showed one relatively stable situation (sampling point stations very close in the representing plot) in II 2008 and two maxima, one in X 2007 described by the widest distribution of points along the vertical axis, the other in XII 2007 mainly described by the widest distribution along the horizontal axis (Figure 3).

Jellyfishes sampled (*Aurelia aurita*) were patchily distributed throughout the lake. Ephyrae were present in the period XI 2007–IV 2008; adults were present all year round. The jellyfish *Rhizostoma pulmo*

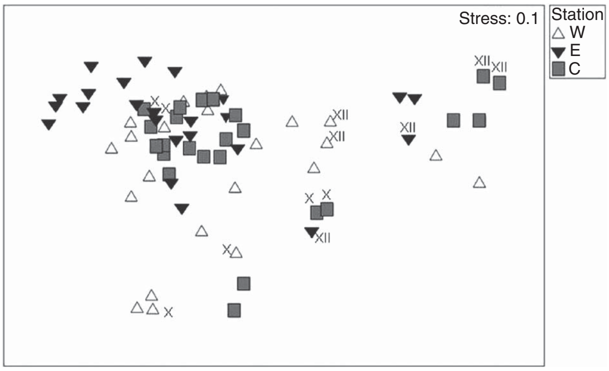

Figure 3. nMDS plot obtained from abundance data (matrix: 55 categories, 71 samples) relative to the period VI 2007–V 2008, from three sampling stations (W, C, E) in Lake Varano. All the samples are represented (two replicates per station, per date). Only the most differentiated dates (X, XII) are indicated.

was also evident in the lake, but it was never caught by the plankton net.

The SIMPER procedure associated with nMDS plot of all samples identified the species responsible for the biotic characterisation of each station (Table III). Acartiidae copepodids and adults, *Oithona nana*, and *Bivalvia* veligers undet. characterised the plankton assemblages of all the three stations, with Stations C showing a considerable abundance of Cirripedia Balanomorpha nauplii.

The qualitative comparison with 1989–90 data allowed us to assess that the total species number did not change significantly in 18 years (43 categories in 1989–90; 47 categories in 2007–08, considering only the 10 months compared), but the two sampling series shared only 28 categories (Table IV).

The current Acartiidae species *Acartia tonsa*, *A. clausi* and *Paracartia grani*, with the exception of *A. clausi*, were absent 18 years ago, when the macroscopic jellyfishes *Aurelia aurita* and *Rhizostoma pulmo* were also absent. However, some species were reported as abundant in 1989–90 (e.g. the copepod *Paracartia latisetosa*), which were completely absent in the 2007–08 samples.

Discussion

The zooplankton of Lake Varano, as is usual for coastal Mediterranean lakes, turned out to be mainly composed of seasonal organisms with large demographic fluctuations. The dominant species (Acartiidae, and Oithonidae of small size) were typical of confined Mediterranean brackish waters (see literature cited in the introduction), even if the presence of *Acartia clausi* could suggest that the degree of confinement of the lake was not extreme. The species, even if adapted to a wide salinity range, is typically absent from coastal lakes having narrow connection with the sea, and/or shallow waters. Both these characteristics are the cause of a minor capacity of the system to buffer sudden variations of weather conditions. The best confirmation of this is the complete absence of *A. clausi* from Lake Lesina (Quarta et al. 1992; Sei & Ferrari 2006), close to Lake Varano, and with a comparable area, but with an average depth of only 0.5 m.

The community composition was not significantly different at the three sampling points studied, with the exception of two periods, X and XII 2007, when the sampling stations segregated evidently. This suggests that, apart from these two dates, the lake community is mainly homogeneous and it varies synchronously. From the analysis of the species composition, it is evident that the E station was affected by abundance peaks (mainly due to *A. tonsa*), which did not impact the other two stations. It is interesting to note that *Aurelia* (a possible predator on zooplankton) is practically absent only from the E station, suggesting that the lower zooplankton level in the other two stations likely depends on the medusa predation on the copepods. In addition, station E showed organisms coming from the sea (*Ctenocalanus* sp., *Paracalanus* sp., *Centropages typicus*, Corycaeidae) probably due to a better functioning of the east canal in comparison with the west one. On the other hand, station W showed some freshwater-derived species (*Daphnia* sp., *Calanipeda aquaedulcis*, Rotifera) probably due to the proximity with some freshwater springs well known in that area. These presences, however, were always numerically scant. The C station was characterised by the lowest abundances and by the accumulation of specimens of some categories (Cirripedia Balanomorpha nauplii) in short periods.

The zooplankton species composition had a different result from that observed in 1989–90. The most evident change was the presence of *Acartia tonsa* as the dominant species, as it was never previously reported for the lake, and only recently reported from the adjacent Lake Lesina (Sei & Ferrari 2006). Other evident changes in the zooplankton composition were represented by some of the Decapoda larvae, and fish larvae and eggs (mainly of the anchovy *Engraulis encrasicolus*). Also the jellyfish *Aurelia aurita*, forming massive populations in Lake Varano, was not reported in 1989–90. The species is a constant presence in Mediterranean-confined basins and seas in the last decade (Benović et al. 2000; Isinibilir et al. 2010); however, it is still absent in the adjacent Lake Lesina. This is probably due to the depth of Lake Varano, being the scyphopolips of *Aurelia* of relatively sciaphilic and needing the adults of a proper space to

Table III. Contribution of taxa to the biotic characterisation of each station (av. ab., average abundance; av. sim., average similarity; contrib. %, contribution percentage; cum %, cumulative percentage).

Taxa	av. ab.	av. sim.	contrib. %	cum. %
Station W				
Acartiidae copepodids	4.32	14.13	18.07	18.07
Acartia tonsa	4.02	11.45	14.64	32.72
Oithona nana	3.75	11.30	14.45	47.17
Bivalvia veliger undet.	3.52	9.53	12.19	59.36
Polychaeta larvae Spionidae	1.90	4.61	5.89	65.25
Acartia clausi	1.56	3.68	4.70	69.96
Gastropoda veliger undet.	1.24	3.63	4.65	74.60
Decapoda Natantia zoea	1.21	3.23	4.13	78.73
Longipedia nauplii	1.23	2.64	3.37	82.10
Cirripedia Balanomorpha nauplii	1.21	2.60	3.33	85.43
Decapoda Brachyura zoea	0.85	2.16	2.76	88.19
Acartiidae nauplii	0.73	1.86	2.38	90.57
Station C				
Acartiidae copepodids	5.77	16.55	20.99	20.99
Acartia tonsa	5.24	14.08	17.86	38.85
Oithona nana	2.85	7.39	9.37	48.22
Polychaeta larvae Spionidae	2.41	6.30	7.99	56.21
Cirripedia Balanomorpha nauplii	2.24	5.76	7.30	63.51
Bivalvia veliger undet.	2.17	5.20	6.59	70.10
Gastropoda veliger undet.	1.48	3.53	4.48	74.58
Acartia clausi	1.36	3.44	4.36	78.94
Harpacticoida undet.	1.31	2.83	3.59	82.53
Acartiidae nauplii	1.22	2.71	3.44	85.97
Decapoda Natantia zoea	1.16	2.43	3.08	89.05
Decapoda Brachyura zoea	0.99	2.12	2.68	91.73
Station E				
Acartiidae copepodids	4.36	14.64	18.70	18.70
Acartia tonsa	3.88	12.40	15.84	34.53
Oithona nana	3.22	10.68	13.64	48.17
Bivalvia veliger undet.	2.66	8.22	10.49	58.67
Polychaeta larvae Spionidae	2.00	6.23	7.96	66.62
Acartia clausi	1.61	4.72	6.03	72.65
Decapoda Brachyura zoea	1.20	3.09	3.95	76.60
Gastropoda veliger undet.	1.24	2.91	3.72	80.32
Longipedia nauplii	1.00	2.49	3.17	83.49
Decapoda Natantia zoea	0.91	2.25	2.87	86.36
Acartiidae nauplii	0.70	2.06	2.63	88.99
Harpacticoida undet.	0.92	1.91	2.44	91.44

migrate along the water column daily (Malej et al. 2007).

Moreover, enclosed habitats characterised by calm waters and high food availability enhance the probability of jellyfish survival, allowing *Aurelia* to reach high densities.

The role of the jellyfishes on the trophic chain of the systems where they stay is not obvious, being alternatively considered as directly affecting the microzooplankton (Malej et al. 2007), or the mesozooplankton (Lo & Chen 2008), or indirectly affecting either the microbial production (Malej et al. 2007; Turk et al. 2008) and the fishery (Lo & Chen 2008). The massive presence of *Aurelia aurita* is typical of the last decade in the Mediterranean basin, but its possible action on the zooplankton composition or abundance is conditioned by its supposed feeding adaptability, and it cannot be clearly derivable from the present study. However, the total abundances of mesozooplankton copepods and the presence of fish larvae (both reported as prey of *Aurelia* by Titelman & Hansson 2006; Lo & Chen 2008; Turk et al. 2008), appeared as negatively correlated with jellyfish presence.

The concurrent presence of the Non Indigenous Species *Acartia tonsa* and *Paracartia grani*, and that of jellyfish and anchovy, attest to the ongoing changes that the lake is experiencing. Such a change is probably due to an improved water exchange with the sea, resulting from an excavation of the already existing channels (Figure 1). This improved water exchange is confirmed not only by the abundance of a marine-derived fauna (jellyfish, anchovies, crustaceans) but also by a progressive rise

Table IV. Comparison among the zooplankton fauna list in the two periods examined. Some species collected in 2007–08 do not appear in the list because the comparison considers only 10 months and one station (W). Bold written categories are the most abundant in each period considered.

Taxon	1989–90	2007–08
Coscinodiscus sp.	x	x
Benthic Foraminifera, undet.	x	x
Tintinnina, undet.	x	x
Hydrozoa medusae, undet.	x	x
Schyphozoa ephyra		x
Aurelia aurita		x
Platyhelminthes, undet.	x	
Nematoda, undet.	x	x
Foronida, actinotrocha	x	x
Bivalvia, veliger	**x**	**x**
Gastropoda, veliger	**x**	**x**
Nereidae larva	x	x
Spionidae larva	**x**	**x**
Polychaeta larva/juvenes, undet.	x	x
Canuellidae nauplius	x	x
Canuella sp.	x	
Euterpina acutifrons	x	x
Longipediidae, nauplius	x	x
Longipedia copepodids		x
Metis ignea		x
Parategastes sp.	x	
Tisbiidae, undet.	x	
Harpacticoida alii, undet.	x	x
Oncaeidae copepodids	x	
Oithona nana	**x**	**x**
Oithonidae copepodids		x
Cyclopina sp.	x	
Halicyclops sp.		x
Acartiidae nauplius	x	x
Acartiidae copepodids	**x**	**x**
Acartia clausi	x	**x**
Acartia margalefi	x	
Acartia tonsa		**x**
Calocalanidae, undet.	x	
Centropagidae nauplius	x	
Centropagidae, undet.	x	x
Centropages kroyeri		x
Centropages ponticus	x	
Centropages typicus		x
Clausocalanus sp.		x
Paracalanus sp.	x	
Paracartia latisetosa	**x**	
Daphnia longispina		x
Podon sp.	x	x
Cirripedia Balanomorpha nauplius	**x**	**x**
Cirripedia cypris		x
Ostracoda, undet.	x	x
Amphipoda, undet.	x	x
Mysidacea, undet.		x
Decapoda Brachyura zoea	x	**x**
Decapoda Natantia zoea	x	x
Hydracarina, undet.	x	x
Chironomidae, larva	x	
Rhincota, larva	x	
Insecta, eggs	x	

(Continued)

Table IV. (Continued).

Taxon	1989–90	2007–08
Chaetognata, undet.		x
Ascidiacea larva, undet.		x
Osteichthyes egg	x	
Osteichthyes, larva		x
***Engraulis* egg**		**x**
Engraulis larva		x
Crested cyst, undet.		x
Total presences	**43**	**47**

of the salinity values recorded in the past 40 years. Blundo et al. (1972) reported a salinity range of 18.7–20.3 in 1971; Caroppo (2000) reported a salinity range of 23.7–29.3 in 1997–98; the present data show a salinity range of 21.60–35.01.

The arrival of *Acartia tonsa* and its successful establishment could simply be a reflection of the lake's ecosystem instability. In fact, the species is invading the Mediterranean from the North and the Baltic Seas, and it cannot be considered as evidence of the ongoing tropicalisation of the Mediterranean Sea. Moreover, the jellyfish *Aurelia aurita* is not considered a subtropical species. It has been classified as a 'boreal-derived' organism by Benović et al. (2000), who reported it from Mljet Island (South Croatia).

The obvious conclusion of the present work is that Lake Varano, probably in representation of other sea-connected coastal lakes, is an unstable, ever-changing system which, however, apparently still does not offer successful hospitality to termophylic species. Lake Varano represents, consequently, an interesting ecological situation, which needs to be monitored carefully in the framework of the present global climate change.

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