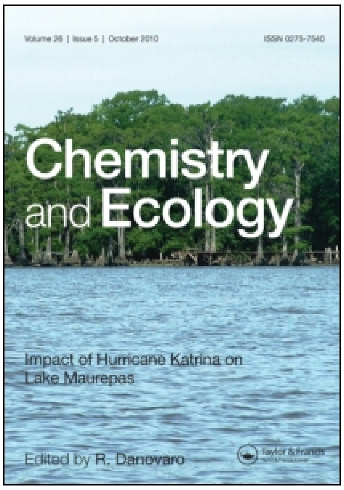

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Research On Zooplankton in the Gulf of Rapallo

S. Sei[a]; P. Licandro[b]; Zunini Sertorio[b]; I. Ferrari[a]
[a] Department of Environmental Sciences, University of Parma, Parma, Italy [b] Institute of Marine Environmental Sciences, University of Genova, Genova, Italy

To cite this Article Sei, S. , Licandro, P. , Sertorio, Zunini and Ferrari, I.(1999) 'Research On Zooplankton in the Gulf of Rapallo', Chemistry and Ecology, 16: 1, 75 — 93
To link to this Article: DOI: 10.1080/02757549908037639
URL: http://dx.doi.org/10.1080/02757549908037639

Chemistry and Ecology, 1999, Vol. 16, pp. 75–93
Reprints available directly from the publisher
Photocopying permitted by license only

RESEARCH ON ZOOPLANKTON IN THE GULF OF RAPALLO

S. SEI[a,*], P. LICANDRO[b], T. ZUNINI SERTORIO[b] and I. FERRARI[a]

[a] *Department of Environmental Sciences, University of Parma, Viale delle Scienze, 43100 Parma, Italy;*
[b] *Institute of Marine Environmental Sciences, University of Genova, Corso Rainusso 14, 16038 S. Margherita L., Genova, Italy*

(Received 24 October 1998; In final form 26 October 1998)

Zooplankton samples, collected in autumn 1996 from two stations in the Gulf of Rapallo, Ligurian Sea (Rapallo Harbour and Prelo Bay, which is a more open site with lower human impacts) were analysed. At both stations, the community was dominated by copepods (mainly juveniles and adults of different species of *Acartia* and *Oithona*) and meroplankton (mainly polychaete larvae). Total zooplankton abundance in the harbour waters was significantly higher than in the nearby bay. The occurrence of *Acartia grani* in Rapallo Harbour and *Pteriacartia josephinae* in Prelo Bay is noteworthy, as they are reported for the first time in the Ligurian Sea, and *A. grani* has not previously been recorded to the Italian coastline. A three-day benthic chamber experiment aimed to quantify nutrient fluxes between the sediment and water column was performed in the Rapallo Harbour: the profound effects of confinement on the composition and abundance of zooplankton within the incubation chamber are discussed.

Keywords: Ligurian Sea; zooplankton; *Acartia* species; benthic chambers

INTRODUCTION

From 30th September to 4th October 1996, a benthic chamber experiment was performed in Rapallo Harbour (Gulf of Rapallo, Ligurian Sea) (Fig. 1) with the aim of characterizing sediment-water column fluxes (Della Croce, this volume; Ciceri and Ceradini, this volume). In parallel, the structure of the benthic macro- and

* Corresponding author.

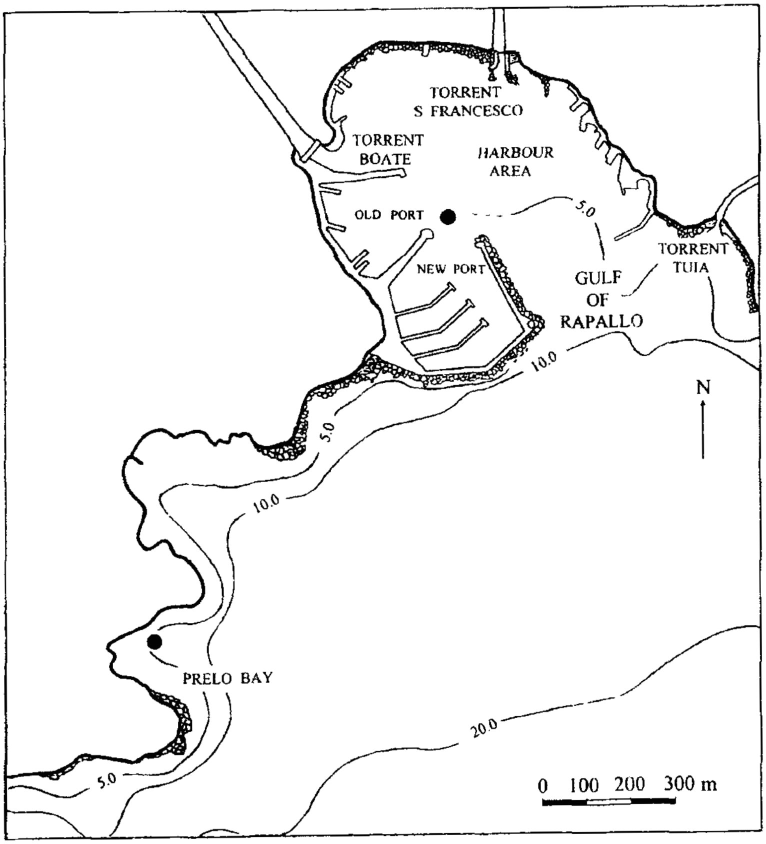

FIGURE 1 Map of the study area showing the locations of the sampling stations in Rapallo Harbour and Prelo Bay.

meiofaunal, protozoan and bacterial communities and the availability and composition of sediment organic matter pools were also characterized (Danovaro *et al.*, this volume; Albertelli *et al.*, this volume). In this study, we have determined the zooplankton community structure over the entire water column and in the near bottom water on samples collected during the same time period within Rapallo Harbour. Zooplankton samples were collected concurrently in the nearby Bay of Prelo (Fig. 1), a more open site with lower human impacts, which is characterized by extensive meadows of the seagrass *Posidonia oceanica*. In addition, a water sample taken from within the benthic chamber at the end of the experiment in Rapallo Harbour was analysed, in order to elucidate changes in zooplankton during the incubation period.

In recent decades, the Rapallo Gulf has been the area of many intensive studies focused on phytoplankton and primary production in the water column, as well as the benthic communities and sediment processes (Danovaro *et al.*, this volume). There are only a few preliminary studies of zooplankton communities, which provide only some fragmented seasonal data (Picone *et al.*, 1978; Basso *et al.*, 1980; Cevasco *et al.*, 1980; Zunini Sertorio, 1980). This study was aimed first to analyse in detail the zooplankton in the Gulf of Rapallo by comparing community structure in two near-shore stations with clearly different trophic conditions and, secondly, to assess the effects of the enclosed chamber incubation on the zooplankton community within the chamber. A summary of preliminary data concerning the benthic chamber experiment was presented by Sei *et al.* (1997) at the national congress of the Italian Ecological Society (Parma, September 1997).

There has been a long tradition of studying zooplankton populations and community structures in enclosed experimental systems (see reviews by Menzel and Steele, 1978; Boyd, 1981; Gamble and Davies, 1982; Harris *et al.*, 1982). These early studies focused primarily on trophic relationships and production processes in the planktonic compartment. However, recent mesocosm studies have also considered planktonic–benthic interactions (Sullivan *et al.*, 1990), differences in the grazing and behaviour of zooplankton size classes (Uitto and Hällfors, 1997) and population life cycles (Klein Breteler *et al.*, 1998). The environmental conditions imposed on zooplankton during the chamber incubation in Rapallo Harbour (confinement within a small volume of the near bottom water) differ greatly from those utilised in previous controlled mesocosm experiments which have focused upon specific aspects of zooplankton ecology and behaviour. Nevertheless, changes in zooplankton populations observed in this benthic chamber incubation are of interest, in order to evaluate the effect of this severe confinement on the populations.

MATERIAL AND METHODS

The benthic chamber used for the experiment had a height of 45 cm (100 l total volume). It was positioned in the inner part of Rapallo

Harbour and maintained *in situ* during three days (71 hours incubation). An automatic device and a continuous stirring system was installed in the chamber to counteract the decrease of pH and dissolved oxygen concentration due to the effects of sediment oxidation processes (Ciceri and Ceradini, this volume).

Zooplankton samples were collected in the harbour water on 30th September, before the benthic chamber was placed and approximately every 8 hours at nine subsequent times until the benthic chamber was removed. The samples were collected vertically from near the bottom to surface (0 – 5 m) with a plankton net (25 cm mouth diameter): each two was repeated three times to obtain a total filtered volume of about 750 litres. Further samples were simultaneously collected in the near bottom layer using a Patalas trap (15 l capacity): three samples were collected and pooled to give a total filtered volume of 45 litres. Additionally, at the end of the benthic chamber incubation, on the 4th October, a sub-sample of 75 l of water was taken from within the chamber by means of a peristaltic pump.

In Prelo Bay, water column (0 – 5 m) and bottom water samples were collected as described above on three occasions, the 30th September and the 1st and 2nd October, respectively.

All samples of zooplankton were collected on a 50 μm mesh net and immediately preserved in a buffered formaldehyde solution (4%) for later examination in the laboratory. Zooplankton counting was carried out on sub-samples taken with a Hansen-Stempel pipette.

Taxonomic identification was made to species or genus level for rotifers, cladocerans, copepods and appendicularians. Copepod nauplii were not classified to species and are considered only as a whole. Identification was made to genus or family for polychaete larvae and all other organisms were classified to higher taxonomic levels.

RESULTS AND DISCUSSION

Rapallo Harbour Zooplankton

The taxa identified in the harbour water samples are listed in Table I: 4 species of rotifers and 3 of cladocerans, 18 taxa of planktonic copepods (9 calanoids, 6 cyclopoids, 2 harpacticoids and 1 monstrilloid)

TABLE I Zooplankton taxa identified on the samples collected in Rapallo Harbour (R) and Prelo Bay (P)

Protozoa	Tintinnidae	R, P	Cladocera	*Pleuroxus* sp.	R	Cirripedia larvae		R, P
	Noctiluca sp.	R, P		*Evadne tergestina*	R	Mysidacea		R
Medusae		R, P		*E. spinifera*	R, P	Cumacea		R
Siphonophora		R		*Penilia avirostris*	P	Anisopoda		P
Actiniaria larvae		R	Ostracoda		R, P	Isopoda		R, P
Turbellaria larvae		R, P	Copepoda			Amphipoda		R
Rotifera	*Brachionus urceolaris*	P	Calanoida	*Paracalanus parvus*	R, P	Decapoda larvae		R
	Keratella cochlearis	R		*Calocalanus* sp.	R	Acari		R
	Colurella sp.	R, P		*Clausocalanus* spp.	R, P	Pantopoda larvae		R
	Lepadella sp.	R		*Temora stylifera*	P	Bryozoa larvae		R
	Synchaeta sp.	R, P		*Temora* sp.	R	Chaetognatha		R, P
Nematoda		R, P		*Centropages* spp.	R, P	Echinodermata larvae		R, P
Gastropoda larvae		R, P		*Isias clavipes*	R	Appendicularia	*Oikopleura* sp.	R, P
Bivalvia larvae		R, P		*Acartia clausi*	R, P		*Fritillaria* sp.	R, P
Polychaeta larvae				*A. adriatica*	P	Ascidiacea larvae		R, P
Aphroditidae		R		*A. grani*	R			
Nephtyidae		R, P		*A. italica*	R, P			
Phyllodocidae		R, P		*Pteriacartia josephinae*	P			
Nereidae		R	Cyclopodia	*Acanthocyclops* sp.	P			
Ariciidae		P		*Oithona nana*	R, P			
Spionidae	*Polydora* sp.	R		*O. similis*	R			

TABLE I (Continued)

	Spio sp.	R, P		*O. plumifera*	R
	Prionospio sp.	R, P		*Oncaea* spp.	R, P
Magelonidae		P		Sapphirinidae	R
Chaetopteridae		P		*Corycaeus* sp.	R, P
Ophelidae		P		*Corycella rostrata*	P
Capitellidae		R	Harpacticoida	*Microsetella norvegica*	R, P
Owenidae		R, P		*Euterpina acutifrons*	R, P
Terebellidae		R, P		*Ectinosoma* sp.	R
Sabellariidae		R, P		*Tisbe* sp.	R, P
				Harpacticus sp.	R
				Parategastes sphaericus	R
			Monstrilloida		R, P

and 4 of benthic copepods were identified; meroplankton forms belonging to 11 main taxa and 9 polychaete families were also recorded.

Over the four day sampling period, zooplankton abundances varied in the range 46–136 ind$\cdot l^{-1}$ (mean: 81.8) in the near bottom water and in the range 43–120 ind$\cdot l^{-1}$ (mean: 77.2) over the entire water column (Tab. II); the highest density values were observed during the first two days (Fig. 2). The community was characterized by the dominance of copepod nauplii (Fig. 2), copepod copepodids and adults (Fig. 3) and meroplankton (Fig. 4), followed by rotifers and appendicularians. Other groups were also present at very low densities and together accounted for 2.3% and 1.6% of total zooplankton in the near bottom and over the entire water column, respectively. Despite the riverine inputs to the harbour, the presence of typical freshwater zooplankton (rotifers, cladocerans) was quite negligible.

Density differences between the water column and near bottom sample series (tested using the two-tailed t test for paired samples) were not significant for copepods (both nauplii and copepodids and adults), rotifers and meroplankton, while a significant difference ($p < 0.05$) was found for appendicularians, which were more abundant in the near bottom layer.

Copepods represent on the average more than 70% of the total zooplankton: the percent importance of nauplii was approx. 50% in the near bottom layer and approximately 57% in the water column; copepodids and adults, which were the most significant fraction in terms of biomass, comprised more than 20% of the total zooplankton in both water column and near bottom waters. The species composition of this fraction of the community is listed in Table III. The dominant species were *Acartia italica*, *Oithona nana* and *Euterpina acutifrons*, as noted in previous zooplankton studies in Ligurian harbour waters (Picone *et al.*, 1978; Basso *et al.*, 1980; Cevasco *et al.*, 1980; Zunini Sertorio *et al.*, 1980). Other species of *Oithona* (*O. similis* and *O. plumifera*) and *Acartia* (*A. clausi*), which are typical of neritic zooplankton, were also found at lower densities. The occurrence of *Acartia grani* is noteworthy, as this species, which appears to have a broad geographical distribution and has previously been observed in southern Mediterranean basins, *e.g.*, the Malaga Bay (Rodriquez, 1983; Rodriguez *et al.*, 1995), and both the European and African

TABLE II Densities and percent contribution of the main zooplankton groups in Rapallo Harbour samples collected in the near bottom water, over the entire (0–5 m) water column and inside the benthic chamber at the end of the incubation (see text)

	Near bottom				*Water column*				*Benthic chamber*	
	Sep 30	*Sep* 30–*Oct* 3(N = 9)			*Sep* 30	*Sep* 30–*Oct* 3(N = 9)			*Oct* 4	
		Average		*Range*		*Average*		*Range*		
	ind l^{-1}	*ind* l^{-1}	%	*ind*/l^{-1}	*ind* l^{-1}	*ind* l^{-1}	%	*ind* l^{-1}	*ind* l^{-1}	%
Copepods										
nauplii	77	40.6	49.6	22–77	55	44.3	57.4	15.9–65.2	85	92.8
adults and copepodids	27.4	17.9	21.8	8.8–31.2	20.3	15.8	20.4	9.1–30.2	5.8	6.3
Meroplankton	12.2	10.1	12.3	5.6–15.2	6	7.8	10.1	3.5–14.5	0.4	0.4
Rotifers	6	6.0	7.3	1–16	6.9	4.2	5.5	2–10.2		
Appendicularians	11.2	5.5	6.7	2–11.2	6.5	3.8	4.9	1.2–6.5		
Others	2	1.8	2.3	0.6–4.2	1.7	1.3	1.6	0.5–2.1	0.4	0.4
Total zooplankton	135.8	81.8	100	46.2–135.8	96.4	77.2	100	43.1–119.7	91.6	100

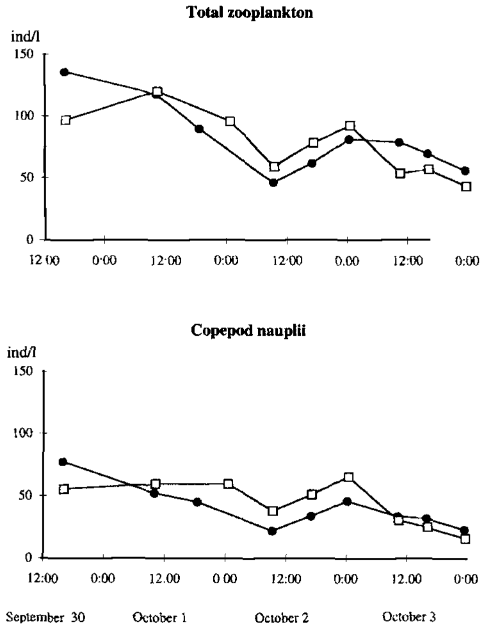

FIGURE 2 Variations in total zooplankton and copepod nauplii densities over the entire water column (-□-) and in the near bottom waters (-•-) of Rapallo Harbour.

Atlantic coastlines (Diouf and Diallo, 1990; Sautour and Castel, 1993), has never been reported on the Italian coastline (G. Belmonte, pers. comm.). On the whole, *Acartia* spp., *Oithona* spp. and *Euterpina acutifrons* accounted for approx. 80% of the total density of copepod copepodids and adults in the water column and approx. 70% of that in the near bottom layer (Fig. 4).

Meroplankton consisted mainly of polychaete, bivalve and gastropod larvae (Tab. IV, Fig. 4), whose density ranges, in the total of 18 samples examined, were 0.8–11.4, 0.8–5.3 and 0.1–1.2 ind·l^{-1}, respectively. Polychaete larvae were mainly represented by species belonging to Sabellariidae and Spionidae.

Rotifers consisted almost exclusively of the genus *Synchaeta* and appendicularians were represented by the genera *Oikopleura* and *Fritillaria*.

The comparison between our data and those of previous studies in Rapallo Harbour was only possible for the meroplanktonic component

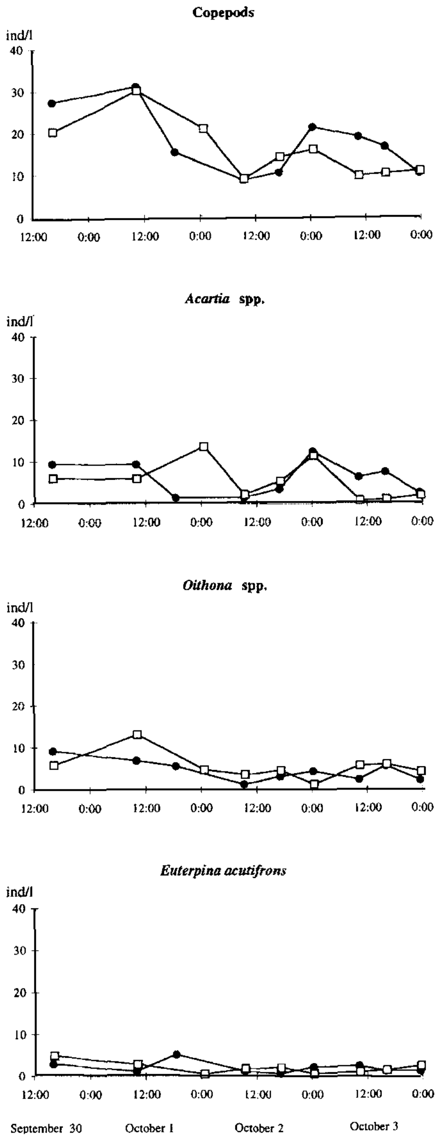

FIGURE 3 Variations in the densities of copepodids and adults of total copepods and of the dominant species over the entire water column (-□-) and near bottom waters (-•-) of Rapallo Harbour.

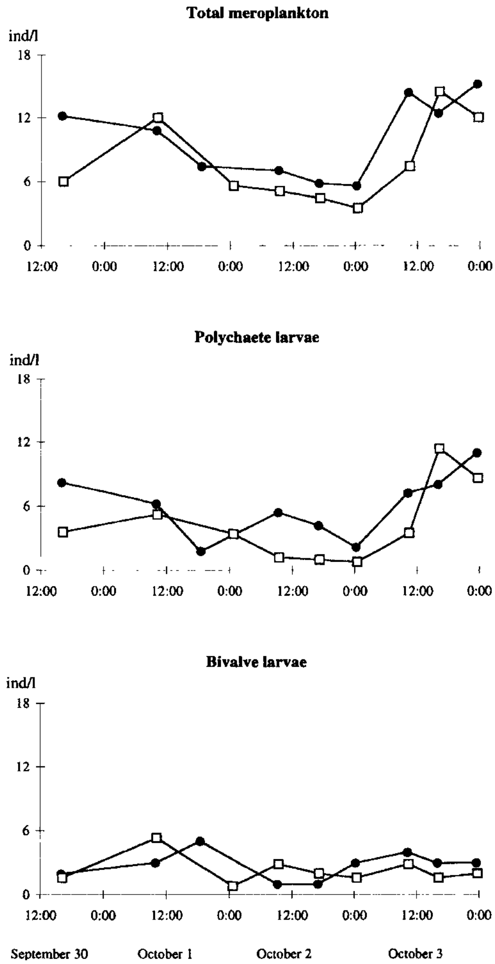

FIGURE 4 Variations in total meroplankton and polychaete and bivalve larvae densities over the entire water column (-□-) and in the near bottom waters (-•-) of Rapallo Harbour.

investigated during the 1970's. Zooplankton samples in the harbour were collected using a 92 μm mesh net in summer 1972 (Picone *et al.*, 1978), autumn 1974 (Basso *et al.*, 1980) and spring 1975 (Cevasco *et al.*, 1980): the density values of the main meroplankton taxa were

TABLE III Densities and percent composition of the copepod copepodids (**c**) and adults (**a**) in Rapallo Harbour in the near bottom waters, over the entire (0–5 m) water column and inside the benthic chamber at the end of the incubation (see text)

		Near bottom					*Water column*			*Benthic chamber*	
		Sep 30	*Sep* 30–*Oct* 3 (*N* = 9) *Average*		*Range*	*Sep* 30	*Sep* 30–*Oct* 3 (*N* = 90) *Average*		*Range*	*Oct* 4	
		$ind\,l^{-1}$	$ind\,l^{-1}$	%	$ind\,l^{-1}$	$ind\,l^{-1}$	$ind\,l^{-1}$	%	$ind\,l^{-1}$	$ind\,l^{-1}$	%
Paracalanus parvus	**a, c**		0.27	1.5	0–1	0.1	0.31	2.0	0–0.9		
Calocalanus sp.	**a, c**		0.07	0.4	0–0.2	0.1	0.16	1.0	0–0.8		
Clausocalanus spp.	**a, c**		0.11	0.6	0–0.6	0.4	0.36	2.3	0–0.9	0.2	3.4
Temora sp.	**c**						0.01	0.1	0–0.1		
Centropages sp.	**a**						0.03	0.2	0–0.1		
Centropages sp.	**c**	2	0.60	3.4	0–2	0.8	0.18	1.1	0–0.8		
Isias clavipes	**a, c**	0.2	0.60	3.4	0–2.2		0.28	1.8	0–0.8		
Acartia clausi	**a**		0.07	0.4	0–0.2	0.2	0.06	0.4	0–0.2		
A. grani	**a**		0.07	0.4	0–0.2		0.13	0.8	0–0.5		
A. italica	**a**	0.4	1.13	6.3	0.2–2.2	0.1	0.76	4.8	0.1–2.8	0.4	6.9
Acartia spp.	**c**	9.0	4.67	26.1	1–10	5.7	4.34	27.5	0.4–10.2	0.2	3.4
Unident. calanoids	**c**	3	2.13	11.9	0–10	1.6	1.04	6.6	0–5.7		
Oithona nana	**a**	1	0.64	3.6	0.2–1	0.8	0.76	4.8	0.4–1.2	0.2	3.4
O. similis	**a**		0.04	0.2	0–0.2	0.1	0.01	0.1	0–0.1		
O. plumifera	**a**		0.04	0.2	0–0.2		0.19	1.2	0–0.9		
Oithona spp.	**c**	8.2	3.80	21.3	1–8.2	4.9	4.47	28.3	0.8–11.8	3.2	55.2
Oncaea sp.	**a, c**	0.2	0.38	2.1	0–1	0.4	0.21	1.3	0–0.6	0.2	3.4
Sapphirinidae	**a, c**						0.02	0.1	0–0.1		
Corycaeidae	**a, c**		0.02	0.1	0–0.2	0.1	0.08	0.5	0–0.1		
Microsetella norvegica	**a, c**		0.16	0.9	0–1		0.03	0.2	0–0.1	0.2	3.4
Euterpina acutifrons	**a, c**	3	2.02	11.3	0.6–5.2	4.9	1.93	12.2	0.5–4.9		
Monstrillidae	**a, c**	0.2	0.04	0.2	0–0.2		0.04	0.3	0–0.1		
Benthic copepods	**a, c**	0.2	0.76	4.2	0–2.2		0.26	1.6	0–0.5	1.2	20.7
Unident. copepods	**a, c**		0.24	1.4	0–1	0.1	0.13	0.8	0.1–0.4		
Total copepods		27.4	17.8	100	8.8–31.2	20.3	15.8	100	9.1–30.2	5.8	100

TABLE IV Densities and percentages of the main meroplankton groups in Rapallo Harbour: values for samples collected over the entire water column in the seventies and average densities in the near bottom layer and over the entire water column in this study (Sep–Oct 1996)

	Picone et al. (1978) *Jul* 1972		*Basso et al.* (1980) *Oct* 1974		*Cevasco et al.* (1980) *May* 1975		*This study* near bottom		*This study* water column	
	ind l^{-1}	(%)	*ind* l^{-1}	(%)	*ind* l^{-1}	(%)	*ind* l^{-1}	(%)	*ind* l^{-1}	(%)
Polychaeta larvae	0.33	23.1	0.19	57.6	–		6.02	59.7	4.3	54.9
Bivalvia larvae	0.95	66.4	0.05	15.2	0.19	44.2	2.78	27.6	2.3	29.4
Gastropoda larvae	–		–		–		0.64	6.3	0.64	8.2
Cirripedia larvae	0.05	3.5	0.09	27.3	0.24	55.8	0.38	3.8	0.23	2.9
Bryozoa larvae	0.05	3.5	–		–		0.16	1.6	0.19	2.4
Ascidiacea larvae	0.05	3.5	–		–		0.07	0.7	0.04	0.5
Others	–		–		–		0.04	0.4	0.12	1.5
Total meroplankton	1.43	100	0.33	100	0.43	100	10.09	100	7.83	100

summarised by Zunini Sertorio (1980) and are reported in Table IV. The comparison shows very great differences with an apparent increase in densities of all meroplankton taxa during the last two decades. However, much, if not all, of these increases are probably due to differences in sampling methods, especially the use in the previous studies of a larger mesh size, which would result in an underestimation of total populations and especially of the smaller size fractions of the community.

Prelo Bay Zooplankton

The list of taxonomic units identified in Prelo Bay is reported in Table I. The densities of total zooplankton and its major components were considerably lower than in Rapallo Harbour. The comparison was performed between samples gathered at around the same hour on the three sampling days at both stations (Tab. V). On only two occasions (on 30th September, sample from near bottom and 2nd October, sample from the entire water column) the total densities in Prelo Bay (52 and 73.5 $ind \cdot l^{-1}$, respectively) were comparable with those recorded in Rapallo Harbour. Copepod nauplii were dominant with densities ranging from 47% to 67% of the total community. The percentage importance of copepod copepodids and adults, mainly represented by species of the "*Acartia* complex" and *Oithona nana*, ranged from 11% to 36%. Meroplankton (from 8% to 13% of total density) comprised principally of polychaete larvae (mostly Spionidae and Sabellariidae, as in Rapallo Harbour) and gastropod larvae; bivalve larvae occurred with low abundances. Appendicularians showed a relevant numerical importance ranging from 1.5 to 14% of total zooplankton, whilst rotifers were scarce and totally absent in two samples from the near bottom layer.

Four species of the *Acartia* complex coexisted: *A. italica*, which was the most abundant, *A. caulsi*, *A. adriatica* and *A. josephinae*. Belmonte (1998) has recently proposed the inclusion of the last species in a new genus of Acartiidae, *Pteriacartia*. The occurrence of *Pteriacartia josephinae* in the Gulf of Rapallo is remarkable, as previously it has been found in different areas of southern Mediterranean (Crisafi, 1974; Belmonte *et al.*, 1989; Lakkis, 1994; Belmonte, 1998) and has never been recorded in Ligurian Sea or other northern Mediterranean basins.

TABLE V Densities ($ind \cdot l^{-1}$) of the main zooplankton groups in Rapallo Harbour and Prelo Bay in samples collected in the near bottom water and over the entire water column

	Near bottom						Water column					
	Rapallo Harbour			*Prelo Bay*			*Rapallo Harbour*			*Prelo Bay*		
	Sep 30	*Oct* 1	*Oct* 2	*Sep* 30	*Oct* 1	*Oct* 2	*Sep* 30	*Oct* 1	*Oct* 2	*Sep* 30	*Oct* 1	*Oct* 2
Copepods												
nauplii	77	52	22	28	13	15	55	59.1	37.9	27.2	21.5	34.5
adults and copepodids	27.4	31.2	8.8	6	10	8.2	20.3	30.2	9.1	7.6	3.9	21
Meroplankton	12.2	10.8	7	6.4	3.4	3.6	6	12	5.1	3.2	5	7.1
Rotifers	6	13	5	1	–	–	6.9	10.2	3.7	0.1	0.3	2.3
Appendicularians	11.2	7	2	7	0.4	1.2	6.5	6.1	2.4	1.8	5	4.9
Others	2	3.4	1.4	3.6	0.6	0.6	1.7	2.1	1	0.5	0.8	3.5
Total zooplankton	135.8	117.4	46.2	52	27.4	28.6	96.4	119.7	59.2	40.4	36.5	73.5

Zooplankton Changes within the Benthic Chamber

Zooplankton in the benthic chamber at the end of the experiment showed a total density (91.6 ind$\cdot l^{-1}$) within the range observed in the harbour waters over the experimental period. However, the community structure differed greatly from that at the beginning of the incubation. The "residual" community consisted primarily of copepod nauplii (93%) and copepod copepodids and adults (6%), almost exclusively represented by *Oithona* spp. and benthic species. The other zooplankton components, meroplankton, rotifers and appendicularians, underwent an abrupt decline or disappeared totally (Tabs. II, III).

The high abundance of nauplii was probably due to the hatching during the experimental period of copepod eggs present in the water or sediment and the confinement within the chamber which prevented migration. However, no similar concentration effect for other zooplankton components, in particular meroplankton, was observed, indicating that concentration was not the only reason for the dominance of the nauplii within the chamber. Conversely, the observed declines in some zooplankton components cannot be explained by changes in physico–chemical conditions within the chamber, as oxygen and pH were controlled and there was little accumulation of toxic ions (S^{2-}, Fe^{2+}, NH_4^+, NO_2^-) from the sediment (Ciceri and Ceradini, this volume). Therefore, it would appear that con- finement itself was a factor involved in the observed changes in populations and community structure.

Several studies (Roman *et al.*, 1993; Stalder and Marcus, 1997) have indicated that copepod eggs and nauplii have a great tolerance to adverse conditions, *e.g.*, hypoxia, than copepodids and adults. Cyclopoids such as *Oithona* have also been shown to be more resistant to harsh conditions than other copepods, because of their low metabolism (Lampitt and Gamble, 1982; Roman *et al.*, 1993). Thus, the densities of copepod nauplii, *Oithona* and benthic copepods observed at the end of the experiment may reflect a greater tolerance of these forms to confinement.

CONCLUSIONS

1. The intensive field programme, September–October 1996 in the Gulf of Rapallo, incorporating multiple sampling over a relatively

short time period, provided the first detailed description of zooplankton communities in this area. The sampling over the entire water column and in the near bottom layer and the use of a much smaller mesh size (50 µm) than is commonly utilised by marine planktologists allowed the identification of a long and comprehensive list of forms, including taxa never before recorded in the Ligurian Sea (Tab. I). This methodology was particularly fruitful for determining species of the smaller size fraction of the community, whose populations have been probably greatly underestimated in previous studies using large meshes (Tab. IV).

2. Comparison of the Rapallo Harbour area (Tab. II) and the relatively unimpacted Prelo Bay (Tab. V) showed higher zooplankton densities and biomasses to be present in the harbour, as is typical of eutrophiced areas receiving high nutrient inputs. However, despite the undoubted human impact in the harbour area, the diversity, evaluated as richness of the identified taxonomic units, was similar to that found in the open Bay of Prelo. This high level of biodiversity within the harbour indicates that the overall health of the system has not been compromised severely.
3. The occurrence of *Acartia grani* (never previously recorded in Italian coastal waters) in Rapallo Harbour and *Pteriacartia josephinae* (never previously recorded in the Ligurian Sea) in Prelo Bay is of relevant interest. One may speculate that the appearance of these species may represent a further case of biological invasion, as has been described for *Acartia tonsa*, which successfully colonised many Adriatic lagoons during the 1980's (Sei *et al.*, 1996). Our findings indicate that a more intensive research effort should be directed to describing the distribution of the "*Acartia* complex" species in Mediterranean coastal waters and the major biological and ecological traits of populations of this species group, which may provide effective bioindicators of environmental quality (Belmonte *et al.*, 1989).
4. Our data from the benthic chamber experiment (Tabs. II, III) indicate that confinement can affect significantly zooplankton populations. These preliminary data demonstrate that studies of confinement effects on zooplankton population biology, using *in situ* incubation systems, may be a fruitful field for future research efforts, particularly with respect to the understanding of benthos-plankton coupling in shallow water environments.

Acknowledgements

This work was undertaken as a part of the Research Programme "Community Experiments using Benthic Chambers" financially supported by the Ministero Ricerca Scientifica e Tecnologica of the Italian Government. The authors wish to thank Mr. F. Sartore (Department of Environmental Sciences, University of Parma) and Dr. M. Petrillo (Institute of Marine Environmental Sciences, University of Genova) for their technical assistance and Dr. D. Welsh (Department of Environmental Sciences, University of Parma) for help with English.

References

Albertelli, G., Covazzi Harriague, A., Chiantore, M., Danovaro, R. and Della Croce, N. (1998) Community experiments using benthic chambers: 2. Meio and macrofaunal community structure and metabolism. *Chemistry and Ecology*, this volume.

Basso, M. P., Della Croce, N. and Picone, P. (1980) Ecologia e biologia dei porti del Mar Ligure e Alto Tirreno. 8. Popolamento zooplanctonico (ottobre-novembre 1974). Atti 3° Congresso AIOL, Sorrento, 18–20 dicembre 1978, pp. 189–195.

Belmonte, G. (1998) *Pteriacartia*, a new genus of Acartiidae (Calanoida, Diaptomoidae) for *Acartia josephinae* Crisafi, 1974. *Journal of Marine Systems*, **15**, 359–368.

Belmonte, G., Benassi, G. and Ferrari, I. (1989) L'associazione di quattro specie di *Acartia* nel lago di Acquatina (Basso Adriatico). *Oebalia*, **25**, 519–522.

Boyd, C. M. (1981) Microcosms and experimental planktonic food chains. In: Longhurst, A. R. (Ed.). *Analysis of Marine Ecosystems*. Academic Press, London, pp. 627–649.

Cevasco, M. G., Picone, P. and Della Croce, N. (1980) Ecologia e biologia dei porti del Mar Ligure e Alto Tirreno. 10. Popolamento zooplanctonico (maggio 1975). *Atti Società Italiana Scienze Naturali Museo Civico di Storia Naturale. Milano*, **121**, 61–68.

Ciceri, G. and Ceradini, S. (1998) Benthic fluxes and pore water profiles in the Tigullio Gulf. *Chemistry and Ecology*, this volume.

Crisafi, P. (1974) Inquinamento e speciazione: *Acartia josephinae* e *A. enzoi* (Copepoda Calanoida), specie nuove del Mare Mediterraneo. *Bollettino di Pesca Piscicoltura e Idrobiologia*, **29**, 5–10.

Danovaro, R., Pusceddu, A., Covazzi Harriague, A., Marrale, D., Dell'Anno, A., Petrillo, M., Albertelli, G. and Della Croce, N. (1998) Community experiments using benthic chambers: 1. Microbial significance in highly organic enriched sediments. *Chemistry and Ecology*, this volume.

Della Croce, N. (1998) Foreword: Benthic Chambers Experiments. *Chemistry and Ecology*, this volume.

Diouf, P. S. and Diallo, A. (1990) Dominance succession of three *Acartia* spp. in a hyperhaline estuary, the Casamance, Senegal. *Revue d'Hydrobiologie Tropicale*, **23**, 195–208.

Gamble, J. C. and Davies, J. M. (1982) Application of enclosures to the study of marine pelagic systems. In: Grice, G. D. and Reeve, M. R. (Eds.). *Marine Mesocosms*. Springer Verlag, New York, pp. 25–48.

Harris, R. H. Reeve, M. R., Grice, G. D., Evans, G. T., Gibson, V. R., Beers, J. R. and Sullivan, B. K. (1982) Trophic interactions and production processes in natural zooplankton communities in enclosed water columns. In: Grice, G. D. and Reeve, M. R. (Eds.). *Marine Mesocosms*. Springer Verlag, New York, pp. 353–387.

Klein Breteler, W. C. M., Gonzales, S. R., Schogt, N. and Fransz, H. G. (1998) Feasibility of incubation experiments to estimate moulting rates in marine copepods. *Journal of Plankton Research*, **20**, 257–269.

Lakkis, S. (1994) Coexistence and competition within *Acartia* (Copepoda, Calanoida) congeners from Lebanese coastal water: niche overlap measurement. *Hydrobiologia*, **292/293**, 481–490.

Lampitt, R. S. and Gamble, J. C. (1982) Diet and respiration of the small planktonic marine copepod. *Oithona nana*. *Marine Biology*, **66**, 185–190.

Menzel, D. W. and Steele, J. H. (1978) The application of plastic enclosures to the study of pelagic marine biota. *Rapp. P.-V. Réun. Comm. Perm. Int. Explor. Mer*, **173**, 7–12.

Picone, P., Della Croce, N. and Basso, M. P. (1978) Ecologia e biologia dei porti del Mar Ligure e Alto Tirreno. 7. Popolamento zooplanctonico (luglio 1972). Atti 2° Congresso AIOL, Genova, 29–30 novembre 1976, pp. 217–222.

Rodriguez, V., Guerrero, F. and Bautista, B. (1995) Egg production of individual copepods of *Acartia grani* Sars from coastal waters: seasonal and diel variability. *Journal of Plankton Research*, **17**, 2233–2250.

Rodriquez, J. (1983) Study of a neritic planktonic community in the Sea of Alboran Spain 2. The zooplankton cycle. *Boletin del Instituto Español de Oceanografia*, **1**, 19–44.

Roman, M. R., Gauzens, A. L., Rhinehart, W. K. and White, J. R. (1993) Effects of low oxygen waters of Chesapeake Bay zooplankton. *Limnology and Oceanography*, **38**, 1603–1614.

Sautour, B. and Castel, J. (1993) Distribution of zooplankton populations in Marennes Oleron Bay, France. Structure and grazing impact of copepod communities. *Oceanologica Acta*, **16**, 279–290.

Sei, S., Rossetti, G., Villa, F. and Ferrari, I. (1996) Zooplankton variability related to environmental changes in a eutrophic coastal lagoon in the Po Delta. *Hydrobiologia*, **329**, 45–55.

Sei, S., Licandro, P., Zunini Sertorio, T. and Ferrari, I. (1997) Esperimenti su comunità con lutilizzo di camere bentiche: cambiamenti nel comparto zooplanctonico. *S. It. E. Atti.*, **18**, 285–286.

Stalder, L. C. and Marcus, N. H. (1997) Zooplankton responses to hypoxia: behavioral patterns and survival of three species of calanoid copepods. *Marine Biology*, **127**, 599–607.

Sullivan, B. K., Doering, P. H., Oviatt, C. A., Keller, A. A. and Frithsen, J. B. (1991) Interactions with the benthos alter pelagic food web structure in coastal waters. *Canadian Journal of Fishery and Aquatic Science*, **48**, 2276–2284.

Uitto, A. and Hällfors, S. (1997) Grazing by mesozooplankton and metazoan microplankton on nanophytoplankton in a mesocosm experiment in the northern Baltic. *Journal of Plankton Research*, **19**, 655–673.

Zunini Sertorio, T. (1980) Larvas meroplanctonicas en aguas de puertos italianos. *5th International Congress Marine Corrosion and Fouling*, Barcelona, 19–23 May 1980, pp. 61–68.

Zunini Sertorio, T., Della Croce, N. and Picone, P. (1980) Ecologia e biologia dei porti del Mar Ligure e Alto Tirreno. II. Parametri ambientali e popolamento zooplanktonico del Porto di Genova. *Atti dell'Accademia Ligure di Scienze e Lettere*, **37**, 3–21.