Crustacean amphipods from the seagrasses *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica* in the Adriatic Sea (Italy): a first comparison

Anfípodos crustáceos asociados a las fanerógamas *Zostera marina*, *Cymodocea nodosa* y *Posidonia oceanica* en el Mar Adriático (Italia): una comparación preliminar

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Palabras claves: Anfípodos crustáceos, fanerógamas marinas, *Zostera marina*, *Cymodocea nodosa*, *Posidonia oceanica*, Mar Adriático, Mar Mediterráneo.

ABSTRACT

In the framework of a wider research programme aimed at identifying the functioning and the temporal dynamics of seagrass ecosystems along the Italian coasts of the Adriatic Sea, crustacean amphipods were studied in *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica* beds. Data on *Z. marina*, which is very rare in the Mediterranean Sea and is scarcely studied as it concerns amphipods, are of particular interest. Samples were collected by hand net and air-lift sampler in *Z. marina* (- 0.5 m) and *C. nodosa* (- 1.2 m) at Grado (northern Adriatic Sea), and in *P. oceanica* (- 6.5 m) at Otranto (southern Adriatic Sea). First data from ten samples collected in February and May 1997 are given. Fifty-five species (*Z. marina*: 24; *C. nodosa*: 29; *P. oceanica*: 31) in 41 genera and 25 families belonging to 7324 individuals were identified. The cluster and nMDS analyses showed the presence of different assemblages in the three seagrasses. The lowest average dissimilarity was present between *Z. marina* and *C. nodosa* (43.13: air-lift sampler; 51.66: hand net) and the higher between *Z. marina* and *P. oceanica* (81.36: air-lift sampler), and between *C.*

nodosa and *P. oceanica* (77.41: hand net). The species which are dominant and/or discriminate each assemblage are *Dexamine spinosa*, *Perioculodes aequimanus* and *Gammarus insensibilis* in *Z. marina*, *Metaphoxus fultoni*, *Ampithoe helleri* and *Ericthonius difformis* in *C. nodosa*, and the small sized *Apolochus neapolitanus*, *Peltocoxa marioni* and *Stenothoe monoculoides* in *P. oceanica*. The features of the sampling sites and the plant structure play an important role in defining assemblages.

RESUMEN

En el marco de un programa de investigación más amplio destinado a identificar el funcionamiento y la dinámica temporal de los ecosistemas de fanerógamas a lo largo de las costas italianas del Mar Adriático, se estudiaron los crustáceos anfípodos de las praderas de *Zostera marina*, *Cymodocea nodosa* y *Posidonia oceanica*. Los datos de *Z. marina*, que es muy rara en el Mediterráneo y muy poco estudiada en lo que concierne a los anfípodos, son particularmente interesantes. Las muestras se recolectaron con una red de mano y un muestreador por succión en *Z. marina* (- 0.5 m) y *C. nodosa* (- 1.2 m) en Grado (norte del Mar Adriático), y en *P. oceanica* (- 6.5 m) en Otranto (sur del Mar Adriático). Se aportan los primeros datos de diez muestras recolectadas en febrero y mayo de 1997 con 55 especies (*Z. marina*: 24; *C. nodosa*: 29; *P. oceanica*: 31) de 41 géneros y 25 familias pertenecientes a 7324 individuos. Los análisis de cluster y nMDS mostraron la presencia de diferentes comunidades en las tres praderas. La disimilaridad media más baja se registró entre *Z. marina* y *C. nodosa* (43.13: muestreador por succión; 51.66: red de mano) y la más alta entre *Z. marina* y *P. oceanica* (81.36: muestreador por succión), y entre *C. nodosa* y *P. oceanica* (77.41: red de mano). Las especies dominantes que discriminaron las comunidades fueron *Dexamine spinosa*, *Perioculodes aequimanus* y *Gammarus insensibilis* en *Z. marina*, *Metaphoxus fultoni*, *Ampithoe helleri* y *Ericthonius difformis* en *C. nodosa*, y las especies de pequeño tamaño *Apolochus neapolitanus*, *Peltocoxa marioni* y *Stenothoe monoculoides* en *P. oceanica*. Las características de las localidades de muestreo y la estructura de la planta desempeñan un papel fundamental en la organización de las comunidades.

INTRODUCTION

Seagrasses play a fundamental role in coastal benthos, due to their various and complex architecture and their role in amplifying differently the substrata (e.g. Larkum *et al*., 2006). Vagile fauna assemblages are an important component in structuring these ecosystems and in energy transfer from producers to higher consumers (e.g. Kikuchi & Pérès, 1977; Virnstein, 1987; Mazzella *et al*., 1992; Orth, 1992). It is well known that crustacean amphipods are a dominant fraction of seagrass vagile fauna (e.g. Gambi *et al*., 1992; Nelson, 1995) being able to colonize different micro-environments due to a multiplicity of adaptations.

In the Mediterranean Sea, *Posidonia oceanica* (L.) Delile and *Cymodocea nodosa* (Ucria) Ascherson form the most extended meadows (e.g. Mazzella *et al*., 1993; Buia *et al*., 2000; Procaccini *et al*., 2003). Recently, studies on vagile fauna, in general (Scipione *et al*., 1996; Sánchez-Jerez *et al*., 1999; Como *et al*., 2008), and on crustacean amphipod assemblages, in particular (Scipione, 1989, 1994; Zakhama Sraieb *et al*., 2007), were performed on both seagrasses to compare the two systems under different points of view. On the contrary, scanty data on vagile fauna are available for *Zostera marina* L. (Ledoyer, 1966, as *Z. hornemanniana* Tutin, 1936; Çinar *et al*., 1998; Sfriso *et al*., 2001; Yurdabak, 2004; Rueda *et al*., 2009). In the Mediterranean Sea, *Z. marina* is considered to be a relict species, subject to regression phenomena (Buia & Marzocchi, 1995; Bernard *et al*., 2005; Rueda *et al*., 2008); it lives in confined areas as coastal lagoons or sheltered bays, at low depths (Procaccini *et al*., 2003), with the exception of southern Spain (Alboran Sea) (Rueda *et al*., 2008).

In the framework of a wider research programme (PRISMA) aimed at identifying the functioning and the temporal dynamics of seagrass ecosystems along the Italian coasts of the Adriatic Sea (Mediterranean Sea), *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica* were taken into account for a comparative study performed on spatial and temporal scales, at levels of different compartments of the three systems (Mazzella *et al*., 1998; Guidetti *et al*., 2001; 2002). In the present study, first data on crustacean amphipods are presented, aiming at identifying the structure of assemblages and the role of the host-plant.

MATERIALS AND METHODS

Studies were conducted in two different areas:

— in the northern Adriatic Sea, in front of the sea entrance of the Grado coastal lagoon, at 0.5 m depth, in *Zostera marina* (Z) (45°41.921’ N, 13°28.345’ E), which settles on a pelitic sand substrate, and at 1.5 m depth, in *Cymodocea nodosa* (C) (45°41.554’ N, 13°28.279’ E), which grows on sandy bottoms;

— in the southern Adriatic Sea, north of the town of Otranto, at 6.5 m depth in *Posidonia oceanica* (P) (40°10.192’ N, 18°29.029’ E), which grows on organogenic sand and rock.

Samples were collected by SCUBA diving by means of two methods, the hand-towed net (H) (opening frame 40x20 cm) and the air-lift sampler (A) (on 1m square), with a mesh size of 400 µm. First data, obtained in February (F) and May (M) 1997, for a total of ten samples, are taken into account in the present study. All vagile fauna was sorted and crustacean amphipods were identified at species level and counted. The species were assigned to four ethological categories, according to their micro-habitat preferences: epifaunal free-living, epifaunal domicolous, infaunal free-burrowing and infaunal tube-building.

Parameters such as number of species, number of individuals, Shannon-Wiener's diversity index (H') and Pielou's evenness (J) were calculated for each sample. The quantitative dominance (%) of the identified species was calculated for each seagrass at the level of the whole assemblage and of single samples.

Differences between seagrasses and seasons were evaluated for each sampling method. A non-metric Multi-Dimensional Scaling (nMDS) analysis and a cluster analysis, using group-average clustering, were performed on a Bray-Curtis similarity matrix, based on fourth root transformed species abundances. The SIMPER procedure was used to identify the similarity and dissimilarity percentage between groups of samples of the three seagrasses and the two seasons, and to evaluate the contribution of each species. BIOENV analysis was carried out, using a weighed Spearmans' rank correlation coefficient (Clarke & Ainsworth, 1993), to compare amphipod abundance and environmental, and plant variables matrices, in order to assess which variables better explained the observed multivariate patterns. The parameters taken into account were depth, attenuation coefficient of PAR, temperature, salinity, shoot density, Leaf Area Index, leaf biomass, algal epiphyte biomass. Statistical analyses were performed by means of the PRIMER v 5.0 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke & Warwick, 1994).

RESULTS

Descriptive analysis

Fifty-five species (24 in *Zostera marina*; 29 in *Cymodocea nodosa*; 31 in *Posidonia oceanica*) in 41 genera and 25 families were identified (Table I). On the whole, 7324 individuals were found, but only those identified at species level (6784) were taken into account for the analysis of data. Only six taxa were common to the three seagrasses, while 12 were common to *Z. marina* and *C. nodosa*, 4 to *Z. marina* and *P. oceanica*, and 2 to *C. nodosa* and *P. oceanica* (Table I).

The number of species showed, in the two seasons, similar values in *Z. marina* and higher values in May in *C. nodosa*. The air-lift sampler,

Table I.—Crustacean amphipod taxa identified from *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica*, in the samples collected by hand net (H) and air-lift sampler (A). n: number of samples. (*) Species recorded for the first time in the southern area (*P. oceanica*), (**) in the northern area (*Z. marina*, *C. nodosa*), and (^) in both areas.
Tabla I.—Taxones de anfípodos crustáceos identificados de *Zostera marina*, *Cymodocea nodosa* y *Posidonia oceanica*, en las muestras recolectadas con la red de mano (H) y el aspirador (A). n: número de muestras. (*) Especies recolectadas por primera vez en el área sur (*P. oceanica*), (**) en el área norte (*Z. marina*, *C. nodosa*), y (^) en ambas áreas.

	Z. marina		***C. nodosa***		***P. oceanica***	
	H	**A**	**H**	**A**	**H**	**A**
	n=2	**n=2**	**n=2**	**n=2**	**n=1**	**n=1**
Ampelisca diadema (A. Costa, 1853)						3
Ampelisca typica (Bate, 1856)				3		
Amphilochus brunneus Della Valle, 1893	4	1	8	12		
Apolochus neapolitanus (Della Valle, 1893) *	1				3	129
Ampithoe helleri G. Karaman, 1975 *	47	104	128	244	1	4
Ampithoe ramondi Audouin, 1826			12	24		
Ampithoe ind.				23		
Cymadusa crassicornis (A. Costa, 1857)			3	1		
Aora spinicornis Afonso, 1976						6
Leptocheirus guttatus (Grube, 1864) *						4
Microdeutopus gryllotalpa A. Costa, 1853		10	2	14		
Microdeutopus versiculatus (Bate, 1856)			2	1		
Microdeutopus ind.				1		
Aoridae ind.	3					
Colomastix pusilla Grube, 1861			1			
Apocorophium acutum (Chevreux, 1908)		3	9	7		
Corophium acherusicum A. Costa, 1851			4	9		
Corophium insidiosum Crawford, 1937	6	43	7	17		
Corophium ind.	1	32	16	11		
Monocorophium sextonae (Crawford, 1937)		6	3	6		
Siphonoecetes dellavallei Stebbing, 1899 *					1	
Cressa cristata Myers, 1969 *	2					25
Peltocoxa marioni Catta, 1875 *					4	46
Atylus guttatus (A. Costa, 1851)			1	5		
Atylus massiliensis Bellan-Santini, 1975	1	9	17	49		
Atylus vedlomensis (Bate & West., 1862) *						5
Dexamine spiniventris (A. Costa, 1853) *						4
Dexamine spinosa (Montagu, 1813)	1202	838	96	172	3	4
Dexamine ind.						15
Apherusa alacris Krapp-Schickel, 1969			21	1		
Apherusa cf. *chiereghinii* Giordani Soika, 1950 *	177	73	105	83	8	40

Table I.—*Continued.*
Tabla I.—*Continuación.*

	Z. marina		*C. nodosa*		*P. oceanica*	
	H	**A**	**H**	**A**	**H**	**A**
	n=2	**n=2**	**n=2**	**n=2**	**n=1**	**n=1**
Apherusa ind.	6	5	176	74		
Eusiroides dellavallei Chevreux, 1899 *					1	1
Gammarus insensibilis Stock, 1966	65	92	1	6		
Gammarus ind.			1			
Hyale camptonyx (Heller, 1866) *			1		4	12
Hyale ind.			1			
Iphimedia minuta G.O. Sars, 1882 *						6
Gammaropsis ostroumowi (Sowinsky, 1898) *						1
Gammaropsis palmata Stebbing & Robert., 1891 ^	2				1	7
Gammaropsis ind.	1					
Megamphopus cornutus Norman, 1869 *						8
Microprotopus maculatus Norman, 1867		1	5	13		
Ericthonius difformis Milne Edwards, 1830 **	5	66	47	194		
Ericthonius punctatus (Bate, 1857) *						2
Ischyrocerus inexpectatus Ruffo, 1959 *	1				2	3
Leucothoe spinicarpa (Abildgaard, 1789)						1
Liljeborgia dellavallei Stebbing, 1906 *						6
Lysianassa cf. *plumosa* Boeck, 1871 *						1
Nannonyx propinquus Chevreux, 1911 *					2	4
Orchomene cf. *grimaldii* Chevreux, 1890					1	18
Orchomene cf. *humilis* (A. Costa, 1853)		1				
Elasmopus sp.	1					
Melita hergensis Reid, 1939			10	5		
Melita palmata (Montagu, 1804)		1				
Perioculodes aequimanus (Kossmann, 1880) ^	68	606	11	72		1
Perioculodes longimanus (Bate & West., 1868)			20	26		
Perioculodes ind.				17		
Synchelidium haplocheles (Grube, 1864) *						3
Metaphoxus fultoni (Scott, 1890)	11	5	160	663		
Stenothoe monoculoides (Montagu, 1813) *	18	40	36	38	3	31
Caprella acanthifera Leach, 1814 *	7		118	101		5
Caprella sp.	9	7	111	112		
Pseudoprotella phasma (Montagu, 1804) *				2	1	2
Phtisica marina Slabber, 1769 *					1	
Amphipoda ind.	18	42	39	35	2	35

in comparison to the hand net, was able to collect a consistently higher number of species only in *P. oceanica* (Fig. 1). The species sampled by both methods were only 54.17% in *Z. marina*, 86.21% in *C. nodosa*, and 41.94% in *P. oceanica*. The number of individuals was higher in May, in particular in *Z. marina*. Both sampling methods showed similar trends with higher seasonal differences in hand-net samples (Fig. 1). Diversity index and Evenness values showed similar trends by both sampling methods with higher values in *C. nodosa* and *P. oceanica* in May (Fig. 1).

Dominant species were (Table II):

— in *Zostera marina*, *Dexamine spinosa*, *Perioculodes aequimanus*, *Apherusa* cf. *chiereghinii*, *Gammarus insensibilis*; they were more abundant in May with the exception of *G. insensibilis*;
— in *Cymodocea nodosa*, *Metaphoxus fultoni*, *Ampithoe helleri*, *Dexamine spinosa*, *Ericthonius difformis* and *Caprella acanthifera*; only *A. helleri* and *C. acanthifera* were more present in May;
— in *Posidonia oceanica*, *Apolochus neapolitanus*, *Peltocoxa marioni*, *Stenothoe monoculoides* and *Cressa cristata*.

The epifaunal free-living forms were strongly dominant in *P. oceanica* (83.1%), followed by *Z. marina* (71.4%) where infaunal free-burrowing were also important (19.3%). On the contrary, in *C. nodosa* epifaunal domicolous (25.0%) and infaunal free-burrowing (30.9%) showed values comparable to epifaunal free-living forms (43.4%) (Table II).

Statistical analyses

The nMDS analyses performed separately on data obtained, respectively, by hand net and air-lift sampler showed the same bi-dimensional ordination (Fig. 2). Three groups of samples belonging to the three studied seagrasses were identified. The dendrogram plots produced by the hierarchical cluster analysis showed the same results of the nMDS analysis, indicating the level of similarity (%) between the groups. *Posidonia oceanica* assemblage clearly separated from the other two seagrasses. Differences between *Zostera marina* and *Cymodocea nodosa* assemblages resulted more important in samples collected by hand net.

The SIMPER procedure showed that the higher values of similarity among samples were reached in *Zostera marina* (65.13), followed by *Cymodocea nodosa* (64.59), and at a seasonal level, in February (56.82) in comparison to May (40.38). In both cases, the air-lift sampler was able to collect samples characterized by higher similarity values (Table III).

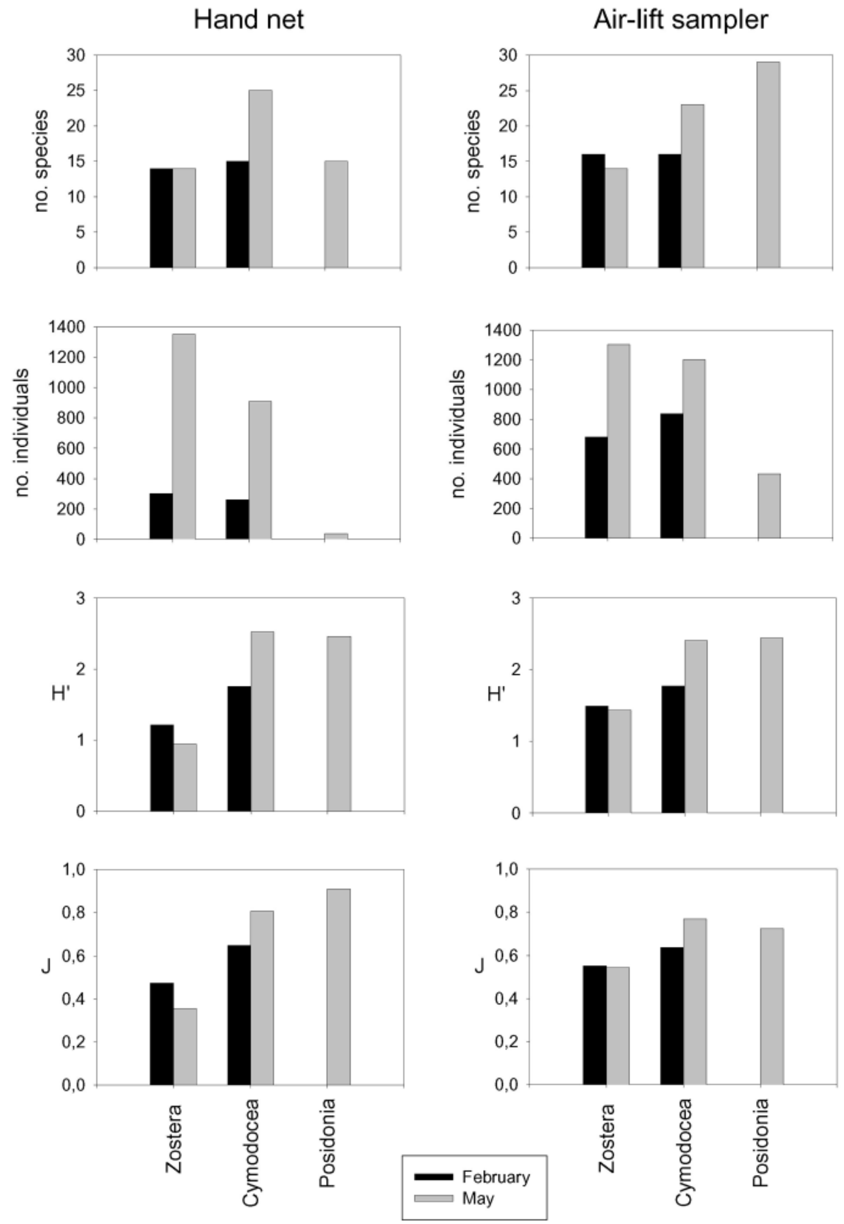

Fig. 1.—Values of amphipod species richness, abundance, Shannon-Wiener's diversity index (H') and Pielou's evenness (J) in *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica*, from samples collected by hand net and air-lift sampler, in February and May.
Fig. 1.—Valores del número de especies de anfípodos, abundancia, diversidad de Shannon-Wiener (H') y equitatividad de Pielou (J) en *Zostera marina*, *Cymodocea nodosa* y *Posidonia oceanica*, de las muestras recolectadas con red de mano y muestreador por succión, en febrero y mayo.

Table II.—Dominance percentage (%) of dominant amphipod species and ethological categories in *Zostera marina* (Z), *Cymodocea nodosa* (C) and *Posidonia oceanica* (P) for each sample, collected by hand net (H) and air-lift sampler (A), in February (F) and May (M), and for the whole assemblage. (*) Species not dominant in the considered sample.
Tabla II.— Porcentaje de dominancia (%) de los anfípodos más importantes y categories etológicas en *Zostera marina* (Z), *Cymodocea nodosa* (C) y *Posidonia oceanica* (P) para cada muestra, recolectadas con red de mano (H) y muestreador por succión (A), en febrero (F) y mayo (M), y para la comunidad completa. (*) Especies no dominantes en la muestra considerada.

Zostera marina						
		ZHF	**ZHM**	**ZAF**	**ZAM**	**Tot.**
Dexamine spinosa		64.7	75.4	54.3	37.2	57.0
Perioculodes aequimanus		8.6	3.1	10.8	42.1	18.8
Apherusa cf. *chiereghinii*		2.0	13.3	0.7*	5.8	7.3
Gammarus insensibilis		15.2	1.4	6.1	4.0	4.4
Ampithoe helleri		1.3	3.2	4.7	5.7	4.2
Ericthonius difformis		1.3*	0.1*	9.5	0.2*	2.0
	Tot. (%)	93.1	96.5	86.1	95.0	93.7
epifaunal free-living		84.2	92.7	63.0	50.5	71.4
epifaunal domicolous		5.6	3.7	25.9	7.0	9.2
infaunal free-burrowing		10.2	3.6	11.1	42.4	19.3
infaunal tube-building					0.1	0.1
	Tot. ind.	303	1335	676	1267	3581

Cymodocea nodosa						
		CHF	CHM	CAF	CAM	Tot.
Metaphoxus fultoni		40.5	6.2	41.1	27.3	26.2
Ampithoe helleri		5.7	13.0	8.7	14.6	11.9
Dexamine spinosa		19.5	5.2	14.9	4.0*	8.5
Ericthonius difformis		11.5	2.0*	18.7	3.2*	7.7
Caprella acanthifera			13.5	2.6	6.8	7.0
Apherusa cf. *chiereghinii*		11.5	8.6	4.1	4.2	6.0
Tot. (%)		88.7	48.5	90.1	60.1	67.3
epifaunal free-living		40.1	68.8	28.5	36.1	43.4
epifaunal domicolous		18.7	21.1	28.1	27.1	25.0
infaunal free-burrowing		40.8	9.6	43.4	35.4	30.9
infaunal tube-building		0.4	0.5		1.4	0.7
	Tot. ind.	262	871	838	1168	3139

Table II.—*Continued.*
Tabla II.—*Continuación.*

		Posidonia oceanica		
		PHM	PAM	Tot.
Apolochus neapolitanus		8.3	32.5	30.5
Peltocoxa marioni		11.1	11.6	11.5
Apherusa cf. *chiereghinii*		22.2	10.1	11.1
Stenothoe monoculoides		8.3	7.8	7.9
Cressa cristata			6.3	5.8
Orchomene cf. *grimaldii*		2.8*	4.5	4.4
	Tot. (%)	52.7	72.8	71.2
epifaunal free-living		77.8	83.6	83.1
epifaunal domicolous		13.9	6.8	7.4
infaunal free-burrowing		8.3	6.8	6.9
infaunal tube-building			0.8	0.7
unidentified			2.0	1.9
	Tot. ind.	36	397	433

Table III.—Values (%) of average similarity and dissimilarity between samples belonging to the three seagrasses and the two seasons, according to the SIMPER analysis.
Tabla III.—Valores (%) de similaridad media y disimilaridad entre las muestras pertenecientes a las tres praderas y las dos estaciones, según el análisis de SIMPER.

	Average similarity		
	All samples	Hand net	Air-lift sampler
Zostera marina	65.13	57.19	71.09
Cymodocea nodosa	64.59	53.93	61.65
Posidonia oceanica	49.31		
February	56.82	49.51	57.33
May	40.38	30.75	34.89
	Average dissimilarity		
Z. marina vs. *C. nodosa*	47.85	51.66	43.13
Z. marina vs. *P. oceanica*	76.96	72.02	81.36
C. nodosa vs. *P. oceanica*	78.12	77.41	77.05
February *vs*. May	55.21	56.02	53.10

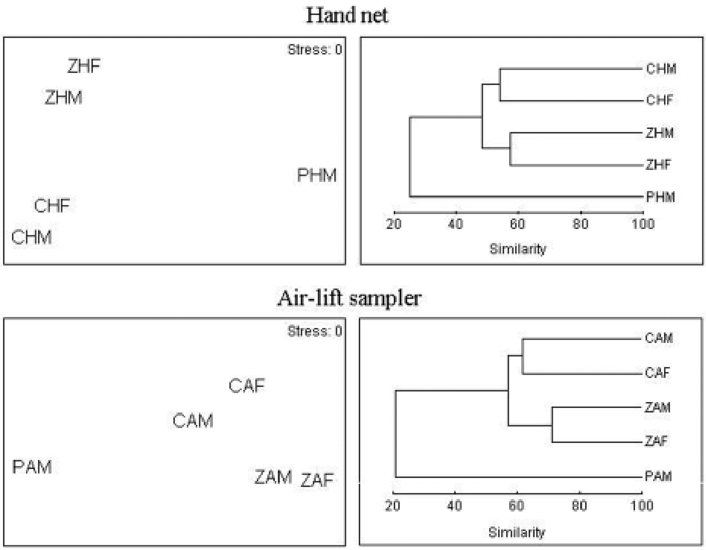

Fig. 2.—nMDS bi-dimensional plots and hierarchical cluster diagrams produced from amphipod species-abundance data collected in *Zostera marina* (Z), *Cymodocea nodosa* (C), and *Posidonia oceanica* (P), by hand net (H) and air-lift sampler (A), in February (F) and May (M).
Fig. 2.—Representación del nMDS bi-dimensional y diagrama de cluster obtenido a partir de las abundancias de las especies de anfípodos recolectados en *Zostera marina* (Z), *Cymodocea nodosa* (C), y *Posidonia oceanica* (P), con red de mano (H) y muestreador por succión (A), en febrero (F) y mayo (M).

The lowest dissimilarity (%) was present between *Z. marina* and *C. nodosa* (47.85), in particular in samples collected by the air-lift sampler (43.13). Dissimilarities between the two seasons were not very high (Table III).

Species which best discriminate between seagrasses are listed according to their whole contribution to dissimilarity, in each combination, up to a cumulative value of 50% (Table IV). Between *Z. marina* and *C. nodosa* the species which best discriminate are mainly the epifaunal *Gammarus insensibilis* and *Dexamine spinosa* (*Z. marina*), and the infaunal *Metaphoxus fultoni* (*C. nodosa*); between *Z. marina* and *P. oceanica* these are again *D. spinosa* and *G. insensibilis* (*Z. marina*), and the epifaunal *Peltocoxa marioni* (*P. oceanica*); between *C. nodosa* and *P. oceanica* these are the epifaunal *P. marioni* and *Apolochus neapolitanus* (*P. oceanica*), the tube-dweller *Ericthonius difformis* and the infaunal *M. fultoni* (*C. nodosa*).

According to BIOENV analysis, depth, attenuation coefficient of PAR, salinity, algal epiphyte biomass and LAI are the environmental and plant parameters which better explain differences of amphipod assemblages between the three seagrasses, by both sampling methods (Table V).

Table IV.—Results of the SIMPER analysis for amphipod species contributing mostly to dissimilarity between groups belonging to the studied seagrasses, *Zostera marina*, *Cymodocea nodosa* and *Posidonia oceanica*. Species are listed according to their contribution to the average dissimilarity up to a cumulative value of 50%.
Tabla IV.—Resultados del análsis de SIMPER para las especies de anfípodos que contribuyen más a la disimilaridad entre grupos pertenecientes a las fanerógamas estudiadas, *Zostera marina*, *Cymodocea nodosa* y *Posidonia oceanica*. Las especies se ordenan de acuerdo a su contribución a la disimilaridad hasta un valor acumulado del 50%.

	Av. Abun.	**Av. Abun.**	**Av. Diss.**	**Diss./SD**	**Contr. %**	**Cum. %**
Zostera marina vs. *Cymodocea nodosa*						
	Zostera	*Cymodocea*				
Metaphoxus fultoni	4.00	205.75	3.48	2.92	7.27	7.27
Dexamine spinosa	510.00	67.00	2.73	2.28	5.71	12.98
Caprella acanthifera	1.75	54.75	2.73	1.61	5.70	18.68
Gammarus insensibilis	39.25	1.75	2.72	3.16	5.69	24.37
Apherusa cf. *chiereghinii*	62.50	47.00	2.63	1.53	5.50	29.88
Perioculodes aequimanus	168.50	20.75	2.10	1.12	4.39	34.27
Caprella sp.	4.00	55.75	1.97	3.30	4.11	38.38
Ampithoe ramondi	0.00	9.00	1.93	1.65	4.04	42.42
Ericthonius difformis	17.75	60.25	1.88	1.67	3.94	46.35
Perioculodes longimanus	0.00	11.50	1.84	1.52	3.85	50.20
Zostera marina vs. *Posidonia oceanica*						
	Zostera	*Posidonia*				
Dexamine spinosa	510.00	3.50	5.74	3.04	7.46	7.46
Perioculodes aequimanus	168.50	0.50	4.83	1.82	6.27	13.74
Gammarus insensibilis	39.25	0.00	4.43	3.35	5.75	19.49
Peltocoxa marioni	0.00	25.00	3.33	10.00	4.33	23.82
Apolochus neapolitanus	0.25	66.00	3.24	2.59	4.21	28.04
Apherusa cf. *chiereghinii*	62.50	24.00	2.97	2.20	3.86	31.89
Ericthonius difformis	17.75	0.00	2.87	1.82	3.73	35.63
Hyale camptonyx	0.00	8.00	2.83	6.96	3.68	39.30
Corophium insidiosum	12.25	0.00	2.56	1.39	3.33	42.63
Orchomene cf. *grimaldii*	0.00	9.50	2.51	6.95	3.26	45.89
Metaphoxus fultoni	4.00	0.00	2.45	2.97	3.19	49.08
Caprella sp.	4.00	0.00	2.39	3.17	3.10	52.18

Table IV.—*Continued.*
Tabla IV.—*Continuación.*

	Av. Abun.	Av. Abun.	Av. Diss.	Diss./SD	Contr. %	Cum. %
Cymodocea nodosa vs. *Posidonia oceanica*						
	Cymodocea	*Posidonia*				
Metaphoxus fultoni	205.75	0.00	5.47	2.91	7.00	7.00
Ericthonius difformis	60.25	0.00	3.98	2.44	5.09	12.09
Caprella sp.	55.75	0.00	3.95	4.24	5.05	17.14
Apolochus neapolitanus	0.00	66.00	3.23	3.17	4.13	21.27
Peltocoxa marioni	0.00	25.00	2.86	4.97	3.66	24.94
Ampithoe helleri	93.00	2.50	2.54	2.38	3.26	28.19
Caprella acanthifera	54.75	2.50	2.52	1.37	3.22	31.41
Dexamine spinosa	67.00	3.50	2.23	2.31	2.85	34.27
Orchomene cf. *grimaldii*	0.00	9.50	2.15	4.30	2.76	37.02
Perioculodes aequimanus	20.75	0.50	2.14	1.49	2.74	39.76
Nannonyx propinquus	0.00	3.00	1.94	4.21	2.48	42.25
Hyale camptonyx	0.25	8.00	1.94	3.32	2.48	44.73
Gammaropsis palmata	0.00	4.00	1.89	5.45	2.42	47.15
Ischyrocerus inexpectatus	0.00	2.50	1.88	3.79	2.41	49.56
Ampithoe ramondi	9.00	0.00	1.88	1.48	2.41	51.97

Table V.—Selections of variables (environmental and plant parameters) which yielded the best correlations between abiotic and biotic similarities of the samples, according to the BIOENV analysis.
Tabla V.—Combinación de variables (ambientales y parámetros de la planta) que mostraron mayores correlaciones entre los parámetros abióticos y bióticos, según el BIOENV.

Variables	Hand net		Air-lift sampler	
	Correlation	Selections	Correlation	Selections
1. Depth				
2. Atten. Coeff. of PAR	0.903	1, 2, 4	0.979	1, 4
3. Temperature	0.899	1, 2	0.964	1, 2, 4
4. Salinity	0.887	1, 4	0.964	1, 4, 8
5. Shoot Density	0.884	1	0.964	1, 2, 4, 8
6. L.A.I.	0.879	1, 4, 8	0.960	1
7. Leaf Biomass	0.879	1, 2, 4, 8	0.952	1, 4, 6
8. Algal Epiphyte Biomass	0.842	1, 4, 6, 8	0.952	1, 2, 4, 6

DISCUSSION

This preliminary study, conducted on a reduced set of samples, highlighted rich, well structured and defined amphipod assemblages.

Some species were reported for the first time in the studied coastal areas, according to the check-list of the Amphipoda in Italian seas (Ruffo, 2010); in particular, 3 species in the northern Adriatic Sea (*Z. marina*, *C. nodosa*) and 26 species in the southern Adriatic Sea (*P. oceanica*) (Table I). The great amount of species firstly reported in the south is probably due to the scarcity of investigation in this geographical area (Diviacco, 1988). In the north, the species *Gammaropsis palmata*, *Ericthonius difformis* and *Perioculodes aequimanus* were not previously reported even along the west coast of Peninsula Istria (Croatia) and the Gulf of Trieste (Krapp-Schickel & Zavodnik, 1993-1996).

The presence of two different assemblages in *Posidonia oceanica* and *Cymodocea nodosa*, as shown in previous studies (Scipione, 1994; Scipione *et al*., 1996; Zakhama Sraieb *et al*., 2007; Como *et al*., 2008), has been confirmed in this geographical area. Data on *Zostera marina*, among the first in the Mediterranean Sea, showed the presence of a peculiar assemblage. This is well diversified if compared to other sites (Çinar *et al*., 1998; Yurdabak, 2004), although it is less structured (lower H' and J values) in comparison to *C. nodosa* and *P. oceanica*.

Depth and correlated factors, as already observed (Mazzella *et al*., 1989; Gambi *et al*., 1992), are crucial variables in defining assemblages, as well as the features and the location of sampling sites (Tanner, 2006). However, the different structure of the plants and its role in modifying the associated micro-environments are of paramount importance (Scipione *et al*., 1996; Boström *et al*., 2006; Como *et al*., 2008).

Zostera marina bed was characterized by harsh environmental conditions — severe excursions of temperature and irradiance according to the season, low salinity (30‰ in February) as well as a silty-sandy sediment — probably related to very shallow depth, low hydrodynamics and fresh-water outflows (Guidetti *et al*., 2002). But, the plant structure (more similar to *P. oceanica* than to *C. nodosa*) and the great amount of plant detritus and floating algae, entrapped at the base and among the leaves (pers. obs.), represent a refuge for vagile forms. This determines the presence of a very rich amphipod assemblage mainly characterized by free-living species related to plant substrata. Structuring taxa were the epifaunal free-living herbivore-deposit feeders *Dexamine spinosa* and *Apherusa* cf. *chiereghinii*, better sampled by hand net being related to the leaf stratum. Furthermore, the infaunal free-burrowing omnivore *Perioculodes aequimanus* and the free-living herbivore *Gammarus insensibilis*, better sampled by the air-lift sampler, being related to the under-canopy layer, were important. *G. insensibilis*, in particular, is probably associated to the great amount of plant detritus found on the bottom.

In *Cymodocea nodosa* bed, the above-mentioned environmental conditions were milder due to higher depth and higher distance from the coast, determining the presence of a better structured amphipod assemblage, very rich in number of species, as similarly observed in *P. oceanica*. The low values of plant parameters as Leaf Area Index and leaf biomass (Guidetti *et al*., 2002) determine the dominance of free-burrowing or tubicolous forms, also associated to the sediment. Structuring taxa were the infaunal free-burrowing *Metaphoxus fultoni*, the tube-dwellers *Ampithoe helleri*, herbivore, and *Ericthonius difformis*, deposit-suspension feeder, as well as the free-living *Dexamine spinosa*, all better sampled in this seagrass by air-lift sampler, apart from the omnivore epifaunal free-living *Caprella acanthifera*, better sampled by hand net.

Posidonia oceanica bed was characterized by high hydrodynamics, an organogenic sandy sediment, and a lower nutrient availability (Guidetti *et al*., 2002), at higher depth, in comparison to the northern area. These factors determined very low abundances, but a rich and well structured assemblage. This is characterized by species strictly related to the micro-environment found on the leaf blades, probably in relation to the above-mentioned factors and to the absence of "matte". These species are the epifaunal free-living small sized *Apolochus neapolitanus*, *Peltocoxa marioni*, *Stenothoe monoculoides* and *Cressa cristata*, along with *A.* cf. *chiereghinii*, the only species which is dominant, although differently, in all the studied seagrasses.

The structure of amphipod assemblages is consistent at a seasonal scale, according to the low values of dissimilarities (Table III), notwithstanding the increasing values (February *vs*. May) of some assemblage parameters, clearly related to higher values of plant parameters (e.g. Leaf Area Index, leaf biomass) (Guidetti *et al*., 2001).

The two sampling methods may be considered complementary, as previously observed (Scipione, 1994; Scipione & Manzi, 1996; Michel *et al*., 2010). Together they provided a more exhaustive view of amphipod assemblages, being able to sample at levels of different compartments of the plants. Both methods, in spite of the differences observed in some dominant species, yielded the same amphipod assemblages for each seagrass. Seasonal differences were better pointed out by hand net method, which samples mainly at leaf stratum level.

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