Research papers

Seasonal variability of suprabenthic crustaceans associated with *Cymodocea nodosa* seagrass meadows off Gran Canaria (eastern Atlantic)

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ABSTRACT

Seagrass meadows are important ecosystems on shallow coastal waters, maintaining a high diversity of species. Mysids are the dominant taxa of suprabenthic organisms associated with seagrass meadows in temperate coastal waters, where they are an important food resource for the coastal fishes. Five meadows of *Cymodocea nodosa* were sampled off the east and west of Gran Canaria Island in spring and autumn 2011 to describe associated suprabenthos and to determine seasonal changes in the abundance of suprabenthos assemblages. Mysids, decapods and amphipods made up 95% of total suprabenthos abundance, which was more abundant in spring (May) than in autumn (November). A total of 29 species were identified, 12 amphipod, 11 decapod and 6 mysid species. The mysid *Leptomysis lingvura* did not show seasonal differences, while *Anchialina agilis* showed greater abundance in May at all localities. For the other mysid species, abundances were higher in May than November, although significant differences varied among localities. The dominant amphipod, *Apherusa vexatrix*, and the dominant decapod, *Hippolyte* spp., also showed significant differences in density between seasons, being higher in May at all localities. From these results, we conclude that there is an overlap between the natural life cycle of the seagrass *C. nodosa* and associated suprabenthos.

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1. Introduction

Seagrass meadows are important ecosystems that contribute to ocean primary and secondary production, and have important ecological and physical functions, being responsible for about 15% of the carbon storage in the ocean (Duarte and Cebrian, 1996; Duarte and Chiscano, 1999). Conservation of seagrass meadows is important, specially because these ecosystems are declining worldwide mainly due to human disturbances (Duarte et al., 2002; Waycott et al., 2009).

Suprabenthos, also called "hyperbenthos", is an important assemblage in coastal ecosystems, exploiting a diversity of food resources: organic particles, detritus, zooplankton, and have an important trophic role as food for juveniles and adults of several commercially important fish species (Mees and Jones, 1997; Cunha et al., 1999). Suprabenthos include mysids, amphipods, cumaceans, isopods, decapods and bottom-dependent polichaetes, which perform regular vertical migrations above the bottom (Sainte-Marie and Brunel, 1985). Recently, there has been an increase in the interest in suprabenthic studies (Mees et al., 1995, 1993b; San

Vicente and Sorbe, 1999, 2001; Dauvin et al., 2011; Dauvin and Pezy, 2013; Dewicke et al., 2003; Azeiteiro and Marques, 1999; Beyst et al., 2001; Cunha et al., 1999; Mouny et al., 2000; Sánchez-Jerez et al., 1999) and their role in trophic chains (Wang and Dauvin, 1994; Mees and Jones, 1997; Cartes et al., 2008, 2011; Madurell et al., 2008; Herrera et al., 2014). Most mysids feed on detritus and are responsible for the remineralization of an important part of refractile detritus (Mees and Jones, 1997). Other studies have shown the importance of suprabenthic mysids for the nitrogen regeneration in the surf zone (Cockcroft et al., 1988).

Mysids are a dominant motile macrofauna in temperate coastal seagrass ecosystems and, as suprabenthos, they are important as food for both juvenile and adult fishes (Mauchline, 1980; Murano, 1999; Herrera et al., 2011; Yamada and Kumagai, 2012). For example, in Gran Canaria Island, Castro (1995) highlighted the importance of mysids as food of *Scomber colias*. This species consumes annually about 242,000 tons of mysids and 29,000 tons of euphausiids.

In the Canary Islands, the seagrass *Cymodocea nodosa* is the dominant vegetal species on soft bottoms in coastal waters along the eastern and southern coasts (Reyes et al., 1995; Pavón-Salas et al., 2000; Barberá et al., 2005). This seagrass provides important ecological functions, such as generation of detritus, habitat creation for omnivorous and herbivorous organisms that transfer

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carbon to high trophic levels, recruitment and nursery habitat for numerous coastal fish species (Espino et al., 2011a, 2011b). The seagrass C. nodosa is legislated as an endangered species by the autonomous government of the Canary Islands (Decreto 151/2001, de 23 de julio, Catálogo de Especies Amenazadas de Canarias). Despite the serious decline of C. nodosa in the past 20 years (Tuya et al., 2013, 2014), environmental protection has been reduced since 2010 (Ley 4/2010, de 4 de junio, del Catálogo Canario de Especies Amenazadas, BOC no 112 de 9/6/10).

In this study, we hypothesized that patterns in the abundance of suprabenthos in the Canary Islands would follow a similar seasonal trend as that displayed by C. nodosa, which shows a maximum production period during spring and summer, and a subsequent senescent period in autumn–winter (Reyes et al., 1995; Tuya et al., 2006). Specifically, we sampled in May (late spring) and November (late autumn) to determine the main taxonomic groups of suprabenthos associated with C. nodosa and their temporal variability. While there are several studies on seasonality of C. nodosa and associated ichthyofauna and macrofauna in the Canaries (Tuya et al., 2001, 2006; Barberá et al., 2005; Espino et al., 2011b, 2011a), there is no study on diversity and seasonality of seagrass associated suprabenthos.

2. Material and methods

2.1. Sampling method

We selected five meadows of C. nodosa in the east and west coast of Gran Canaria: Veneguera, Risco Verde, Roque, Faro and Cabron (Fig. 1). Surveys were conduced in late spring (May 2011) and late autumn (November 2011). In general, the meadows were not only similar in depth, but also presented similarities for a range of environmental factors, particularly sea water temperature, surface PAR and wave exposure (Tuya et al., 2014). Four meadows were located in the east coast, as seagrass meadows are naturally more developed in this stretch of the coast. Table 1 shows the environmental scenario of each meadow.

Samples ($n=4$) were collected during day time using a 6 m-long, 4 m-wide, 0.5 m-high seine net with a mesh size of 1 mm. The net was towed by two SCUBA divers along a 25 m transect parallel to the shore line, collecting a volume of 50 m^{-3}. This net captures small organisms and has been previously used by Espino

et al. (2011a) to collect small fishes in C. nodosa meadows. Samples were fixed in 4% formaldehyde and the main groups were sorted in the laboratory. Mysids, amphipods and decapods were further classified to species level. The suprabenthos abundance was expressed as number of individuals per m^3.

2.2. Statistical analysis

Differences in the abundance of suprabenthos between different seasons (May 2011 vs. November 2011) were tested by means of a 2-way, permutational ANOVA (Anderson, 2001), based on Euclidian distances calculated from square root-transformed data. The ANOVA model included the factors: "Locality" (random factor) and "Time" (fixed factor). P-values were calculated from 999 unrestricted permutations of the raw data. Pairwise comparisons (using 999 permutations) were used, when appropriate, to resolve differences between levels of significant factors.

Multivariate analysis of assemblage structure using multi-dimensional scaling (MDS) was applied to visualize differences in the structure of the entire suprabenthos, and mysid, decapod and amphipod assemblages. For this analysis, we eliminated one replicate from Roque (autumn), because it did not contain any organism. The similarity matrix was calculated by the Bray–Curtis index with a double square transformation of data. The individual contribution of each species to the dissimilarity between seasons was calculated by the SIMPER routine. All statistical analyses were carried out using the PRIMER 6.1 software and PERMANOVA statistical package.

3. Results

3.1. Suprabenthos

Mysids, decapods and amphipods were the main constituents of suprabenthos in C. nodosa seagrasses (65%, 17% and 16% of total abundance respectively), which represent up to 95% of the total suprabenthos abundance (Table 2). During late spring at most locations, mysids constituted the largest fraction, followed by amphipods and decapods. In late autumn, decapods assumed this position, followed by mysids and amphipods (Fig. 3, Table 2).

The MDS showed a pattern of sample aggregation according to seasons (Fig. 4). For the three most abundant groups of
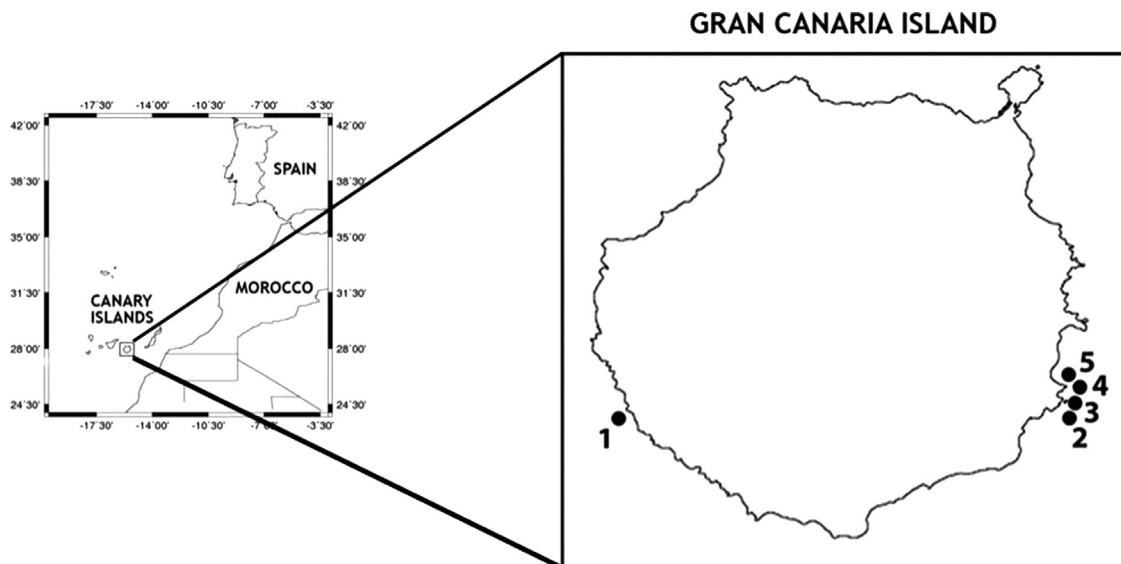

Fig. 1. Map of Gran Canaria showing the location of *Cymodocea nodosa* meadows: 1. Veneguera, 2. Risco Verde, 3. Roque, 4. Faro and 5. Cabron.

Table 1
Environmental scenario of each seagrass meadow (part of data are from Tuya et al., 2014).

Location	Veneguera	Risco Verde	Roque	Faro	Cabron
UTM x	28R 421254	28R 461982	28R 462358	28R 462235	28R 462170
UTM y	3081108	3081367	3081839	3082272	3082906
Depth (m)	10	8	14	10	10
Seagrass area (m^2)	19,683.4	261,550	261,550	261,550	101,638.75
Sediment type	Medium sands	Coarse sands	Medium sands	Medium sands	Medium sands
Mean SST (°C)					
May	20.8	20.8	20.8	20.8	20.8
November	22.4	22.4	22.4	22.4	22.4
Mean PAR (μmol m^{-2} s^{-1})					
May	378.2	378.2	378.2	378.2	378.2
November	174.3	174.3	174.3	174.3	174.3
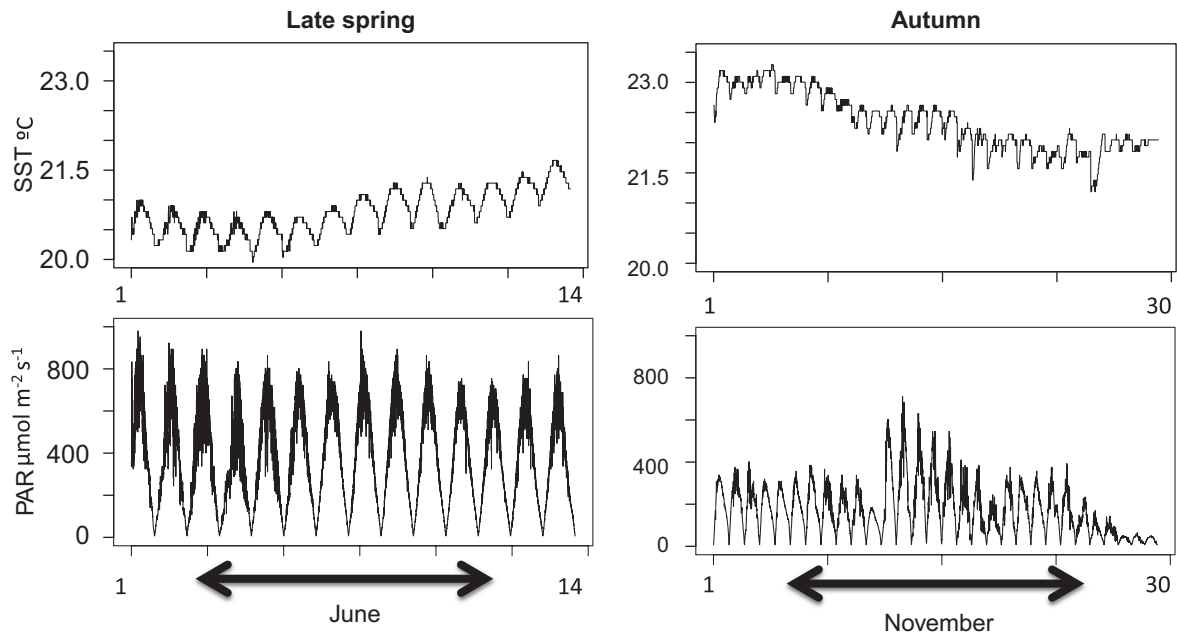
Fig. 2. Photosynthetically Active Radiation (PAR) and Surface Sea Temperature (SST) data in late spring and autumn 2011 in the study area.

suprabenthic crustaceans (mysids, decapods and amphipods), mean abundances showed seasonal differences consistent among localities, being higher in May than in November (2-way ANOVA: $p \leq 0.05$, Table 3; Fig. 3). Average dissimilarity between May and November was 60.94%. The main species that contributed to dissimilarities were *Hippolyte* spp. (11%), *Apherusa vexatrix* (10%), *Latreutes fucorum* (9%), *Gastrosaccus roscoffensis* (8%), *Siriella armata* (7%) and *Leptomysis* sp. (7%).

3.2. Mysids

A total of six species were identified (Table 2): *Siriella armata* (Milne-Edwards, 1837), *Gastrosaccus roscoffensis* (Bacescu, 1970), *Paramysis arenosa* (G.O. Sars, 1877) *Leptomysis* sp. aff. *heterophila* sensu Wittmann and Wirtz (1998), *Anchialina agilis* (G.O. Sars, 1877), and *Leptomysis lingvura* (G. O. Sars, 1866). Only *G. roscoffensis* were present at all *C. nodosa* seagrass meadows at both times (Fig. 5). The species *S. armata* and *G. roscoffensis* showed higher abundances (151.2 ± 113.9 and 42.3 ± 27.5 ind m^{-3}, respectively, mean ± SE) in Veneguera, and *Leptomysis* sp. showed higher abundance (71.3 ± 52.7 ind m^{-3}, mean ± SE) in Faro during late spring (Fig. 5).

Different patterns were observed in temporal variability in mysid abundance. For *L. lingvura*, differences between May and November were not significant (Fig. 5b, 2-way ANOVA: "Time"

$p=0.715$, Table 3). For *P. arenosa*, *Leptomysis* sp. and *G. roscoffensis*, the total abundance was higher in May than in November. However, significant differences varied among localities, resulting in significant "Ti × Lo" interactions (Fig. 5 c, d and e, Table 3). The abundance of *A. agilis* was greater in May than in November (Fig. 5f; 2-way ANOVA: "Time" $p=0.042$, Table 3), independently of the location (Table 3, 2-way ANOVA: "Ti × Lo" $p > 0.05$). Finally, *S. armata* were found only during spring, but no significant differences were detected between seasons; probably, differences were masked by the high variability between replicates at each locality (Fig. 5a; 2-way ANOVA: "Time" $p=0.446$, Table 3). The MDS bidimensional representation showed a separation of mysid assemblages according to seasons (Fig. 8a).

3.3. Decapods

A total of 11 decapod taxa was found (Table 2); five were identified to species level, including *Latreutes fucorum* (Fabricius, 1798), *Palaemon serratus* (Pennant, 1777), *Athanas nitescens* (Leach, 1814), *Processa modica* (Williamson and Rochanaburanon, 1979) and *Calcinus tubularis* (Linnaeus, 1767). Six taxa were identified to genus level, including *Hippolyte* spp., *Philocheras* spp., *Periclimenes* spp., *Sicyonia* spp., *Anapagurus* spp. and *Atelecyclus* spp..

L. fucorum, *Hippolyte* spp., *Philocheras* spp. and *Periclimenes* spp. were present at all samples (frequency occurrence 100%). *Hippolyte*

Table 2
Mean abundance (individuals m^{-3}) of suprabenthos collected in *Cymodocea nodosa* seagrass during late spring (May 2011) and late autumn (November 2011). 1. Veneguera, 2. Risco Verde, 3. Roque, 4. Faro and 5. Cabron.

| Location | 1 | | 2 | | 3 | | 4 | | 5 | |
Sampling time	May	November	May	November	May	November	May	November	May	November
Mysidacea	**211.88**	**3.35**	**22.99**	**2.36**	**13.44**	**0.83**	**74.40**	**1.25**	**8.24**	**1.65**
Siriella armata[a]	151.20	–	0.05	–	0.06	–	0.02	–	0.65	–
Siriella sp.[a]	–	0.02	5.95	0.02	0.36	–	–	–	1.84	0.53
L. lingvura[a]	0.10	0.45	1.10	0.02	0.46	–	–	–	0.20	–
Leptomysis sp.[a]	–	0.05	1.05	0.28	0.88	0.11	71.34	0.06	–	–
Paramysis arenosa[a]	11.78	0.04	–	–	0.44	–	0.46	–	–	0.27
Gastrosaccus roscoffensis[a]	42.34	2.02	0.64	1.95	2.70	0.49	1.54	1.01	0.40	0.81
Anchialina agilis[a]	2.72	0.35	2.92	0.08	3.34	0.23	1.31	0.16	0.34	–
Mysidacea unidentified	3.74	0.43	11.28	–	5.20	–	–	–	4.82	–
Decapoda	**3.53**	**0.71**	**25.77**	**9.19**	**9.56**	**6.12**	**14.6**	**1.23**	**8.18**	**10.20**
Latreutes fucorum[a]	0.38	0.33	6.17	5.94	5.56	5.08	5.96	1.02	4.00	9.10
Hippolyte spp.[a]	1.66	0.12	16.99	2.05	3.90	0.52	8.22	0.15	4.04	0.88
Philocheras spp.[a]	0.96	0.26	0.63	0.29	0.10	0.50	0.06	0.05	0.06	0.12
Periclimenes spp.	0.26	0.01	0.08	0.11	0.14	0.15	0.04	0.02	0.18	0.06
Sicyonia spp.	0.16	–	–	–	–	–	–	–	–	–
Palaemon serratus	–	–	0.02	–	–	–	0.02	–	–	–
Athanas nitescens	0.06	–	–	–	–	–	0.04	–	–	–
Processa modica	0.06	–	–	–	–	–	–	–	–	–
Anapagurus spp.	–	–	–	–	–	0.05	–	–	–	–
Calcinus tubularis	–	–	–	0.01	–	0.02	–	0.01	–	–
Atelecyclus spp.	–	0.01	–	–	–	–	–	–	–	–
Decapoda unidentified	–	–	1.87	0.81	–	–	0.26	–	0.10	0.05
Amphipoda	**17.16**	**0.97**	**22.97**	**2.75**	**8.22**	**1.34**	**20.00**	**1.74**	**7.50**	**2.56**
Apherusa vexatrix[a]	7.52	0.30	6.11	0.60	3.90	0.36	8.10	0.82	2.42	0.66
Dexamine sp.[a]	6.56	0.21	1.20	0.34	0.50	0.19	0.54	0.25	1.08	0.56
Ericthonius punctatus[a]	–	0.01	1.68	0.05	0.70	0.03	0.76	0.03	0.18	0.05
Amphilochus spp.	0.02	–	1.01	0.03	0.44	0.01	0.60	0.03	0.50	0.01
Amphithoe ramondi	0.10	–	0.50	0.04	0.16	0.09	0.48	0.01	0.40	0.08
Peltocoxa mediterranea	–	–	0.40	0.03	0.36	0.05	0.64	0.01	0.14	0.02
Phtisica marina	0.08	0.02	0.41	0.13	0.24	0.12	0.30	0.06	0.06	0.17
Mantacaprella macaronensis	0.28	0.07	0.02	0.03	0.06	0.02	0.02	0.04	–	0.01
Aora spinicornis	–	0.04	0.24	0.07	–	–	0.02	0.01	0.04	0.03
Pseudoprotella phasma	–	–	0.02	0.01	0.06	0.01	0.02	0.06	0.02	0.01
Caprella acanthifera	0.08	–	0.03	–	–	–	–	–	–	–
Caprella liparotensis	–	0.01	–	0.01	–	–	0.04	–	–	0.01
Amphipoda unidentified	2.72	0.34	10.60	1.29	1.44	0.39	7.72	0.37	2.56	0.97
Cumacea	**0.16**	**0.14**	**–**	**0.17**	**–**	**0.20**	**0.42**	**0.22**	**–**	**0.34**
Isopoda	**–**	**–**	**0.30**	**0.01**	**0.04**	**0.01**	**–**	**0.02**	**–**	**–**
Tanaidacea	**–**	**0.12**	**–**	**0.02**	**–**	**0.03**	**–**	**0.01**	**–**	**0.04**
Total suprabenthos	**237.11**	**5.28**	**75.03**	**14.51**	**31.60**	**8.52**	**109.70**	**4.47**	**24.68**	**14.78**

[a] Species contributing more than 2 % of total abundance in any sample.
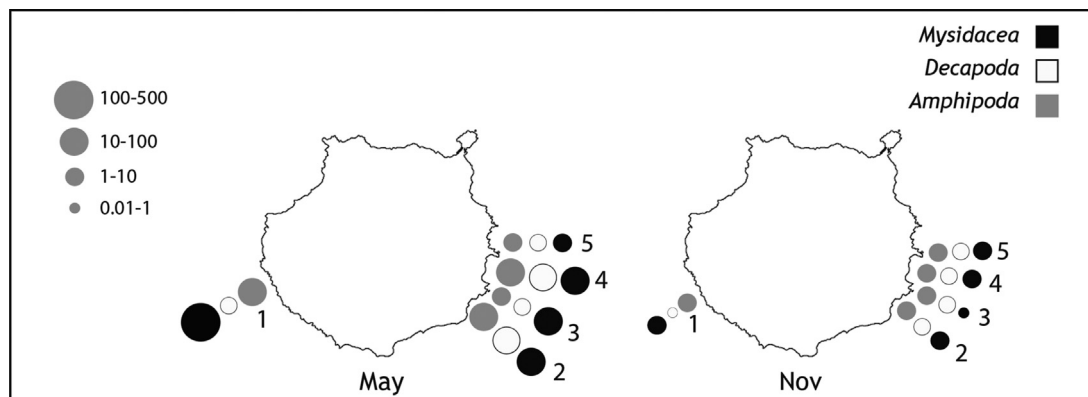
Fig. 3. Mysid, decapod and amphipod abundances (individuals m^{-3}) in May and November 2011. Sampling localities: 1. Veneguera, 2. Risco Verde, 3. Roque, 4. Faro and 5. Cabron.

spp. and *L. fucorum* were the most abundant species, reaching densities of 16.9 ± 7.7 and 9.1 ± 5.5 ind m^{-3}, respectively (mean $\pm$ SE). Only *Hippolyte* spp. showed significant differences in density between seasons, being higher in May at all localities (Fig. 6b; 2-way ANOVA: "Time" $p = 0.006$, Table 3). The MDS ordination plot showed a clear separation of decapod assemblages by seasons (Fig. 8b).
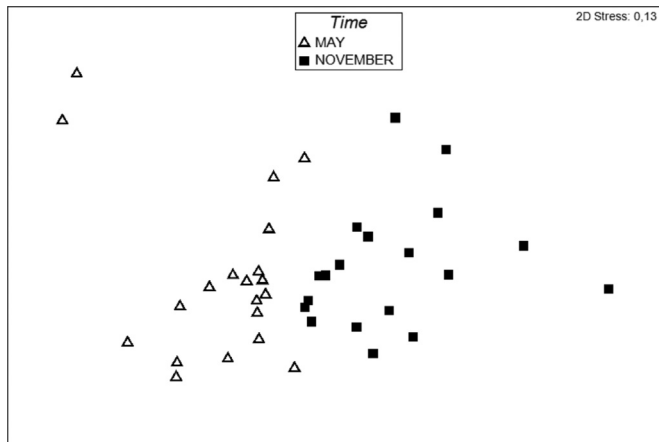
Fig. 4. Multidimensional Scaling (MDS) ordination plot showing similarities in suprabenthos assemblage structure at different sampling times. Triangles: May 2011; squares: November 2011.

3.4. Amphipods

A total of 12 amphipod taxa were identified (Table 2); 10 were identified to species level, including *Apherusa vexatrix* (Krapp-Schickel, 1979), *Amphithoe ramondi* (Audouin, 1826), *Ericthonius punctatus* (Bate, 1857), *Peltocoxa mediterranea* (Schiecke, 1977), *Aora spinicornis* (Afonso, 1976), *Pseudoprotella phasma* (Montagu, 1804)), *Caprella acanthifera* (Leach, 1814), *Caprella liparotensis* (Haller, 1879), *Phtisica marina* (Slabber, 1796) and *Mantacaprella macaronensis* (Vázquez-Luis, Guerra-García, Carvalho and Png-González, 2013). Two to genus level, including *Dexamine* sp. and *Amphilochus* spp..

A. vexatrix, *Dexamine* sp. and *P. marina* were present at all samples. *A. vexatrix* and *Dexamine* sp. occurred at higher abundances (7.5 ± 1.7 and 6.6 ± 4.4 ind m^{-3}, respectively, mean $\pm$ SE) in Veneguera during late spring (Fig. 7). *A. vexatrix* was the only species that showed significant differences between May and November (Fig. 7a; 2-way ANOVA: "Time" $p=0.005$, Table 3), independently of the location (Table 3, 2-way ANOVA: "Ti × Lo" $p > 0.05$). The two-dimensional MDS plot showed a clear segregation of amphipod assemblages by seasons (Fig. 8c).

4. Discussion

The suprabenthic assemblage associated with *C. nodosa* seagrass meadows in Gran Canaria was composed almost entirely by crustaceans of the taxonomic groups: Mysidacea (65% of total abundance), Decapoda (17%) and Amphipoda (16%). These taxonomic groups were also dominant in other suprabenthic studies (Mees et al., 1995, 1993b; San Vicente and Sorbe, 1999, 2001; Dauvin et al., 2011; Dauvin and Pezy, 2013; Dewicke et al., 2003; Azeiteiro and Marques, 1999; Beyst et al., 2001; Cunha et al., 1999; Mouny et al., 2000; Sánchez-Jerez et al., 1999). A total of 29 species were identified, including 12 amphipod species, 11 decapod species and 6 mysid species. The number of mysid, decapod and amphipod species was similar to the number reported by Mees and Hamerlynck (1992) in estuarine and coastal waters (7, 10 and 12 species respectively) and lower than those reported by San Vicente and Sorbe (2001) in seagrass meadows (16, 12 and 10 species, respectively). The number of amphipod species was also lower than that reported by Dauvin et al. (2011), Cunha et al. (1999), and Mouny et al. (2000) in estuarine waters; and Png-Gonzalez et al. (2014) (16 species), Sánchez-Jerez et al. (1999) (28 species) and Vázquez-Luis et al. (2009) (13 species in September and 21 in March), in *C. nodosa* meadows.

The composition of the decapod assemblage is characteristic of seagrass and seaweed meadows, dominated by the family Hippolytidae (*Hippolyte* spp. and *Latreutes fucorum*) (López De La Rosa et al., 2006; Sanchez-Moyano et al., 2001; Sánchez-Moyano et al., 2007; Mateo Ramírez and García Raso, 2012; García-Raso et al., 2006; De Grave et al., 2006). The total number of decapod species was lower than that reported by López De La Rosa et al. (2006) (48), Mateo Ramírez and García Raso (2012) (34), García-Raso et al. (2006) (48) and De Grave et al. (2006) (14). Decapods associated with seagrass meadows typically show diel variation, including larger abundances in the night time, when a more diverse assemblage is present (De Grave et al., 2006; García-Raso et al., 2006). For this reason, we may have underestimated the richness and abundances of species associated with *C. nodosa* meadows.

In the Canary Islands, studies of the suprabenthos composition associated with seagrass meadows are rare. Other authors have studied the macrofauna (Tuya et al., 2001), ichthyofauna (Espino et al., 2011b, 2011a), infauna (Brito and Nuñez, 2001; Monterroso et al., 2012) or epifauna (Png-Gonzalez et al., 2014) associated with *C. nodosa*. However, this is the first study of seagrass-associated suprabenthos in Gran Canaria. The amphipod, *Mantacaprella macaronensis*, has been recently described by Vázquez-Luis et al. (2013); the first record of the mysid *G. roscoffensis* in the Canary Archipelago was only recently published by Wittmann et al. (2010). This reflects the lack of regional taxonomic studies and the need to make additional studies of the composition of suprabenthic fauna in the Canary Islands.

Total suprabenthos densities ranged from 5 to 237 ind m^{-3}, which is the same order of magnitude as those reported by Mees and Jones (1997) in shallow waters and estuaries (1–800 ind m^{-3}). For the English Channel, suprabenthic densities ranged from 1 to 100 ind m^{-3} (Dauvin et al., 2000; Dauvin and Pezy, 2013; Dauvin et al., 2011; Mouny et al., 2000).

Seasonal changes in the total abundance of mysids, decapods and amphipods followed the same pattern that the richness and abundance of ichthyofauna and macrofauna associated with *C. nodosa* in the Canary Islands; maximum values were observed in spring and summer, and minimum values in winter (Tuya et al., 2001, 2006). We observed a relationship between the natural life cycle of *C. nodosa* and associated suprabenthos, this relationship may be directly related to various life-cycles or indirectly to food availability (López De La Rosa et al., 2006). However, other factors such as PAR and temperature could be influencing the phenology of both *C. nodosa* and associated suprabenthos. Our results are in agreement with other studies of seagrass and seaweeds meadows (López De La Rosa et al., 2006; Sanchez-Moyano et al., 2001; Sánchez-Moyano et al., 2007; Kwak and Klumpp, 2004; Mateo Ramírez and García Raso, 2012). The abundance of decapods are related to plant phenology and the dominant species are positively correlated with the number of leaves per shoot in *C. nodosa* (Mateo Ramírez and García Raso, 2012). López De La Rosa et al. (2006) and Sanchez-Moyano et al. (2001); Sánchez-Moyano et al. (2007) also reported a connection between the life cycle of *Caulerpa prolifera* and associated decapods, with maximum decapod abundances coincident with the maximum plant density.

Many mysid species are vertical migrators, living near the surface of the sediment during the day and migrating into the water surface at night (Mauchline, 1980; Macquart-Moulin and Ribera Maycas, 1995; San Vicente and Sorbe, 2013). Here, samples were collected close to the bottom during the daytime, the sampling net was towed 10 cm above the bottom to avoid sediment re-suspension and damages over the seagrass. Unfortunately, sampling suprabenthos is difficult, since some mysid species spend most of the day buried into the sediment or in the first centimeters above the bottom (Mauchline, 1980; Mees and Hamerlynck, 1992). Consequently, it is possible that our sampling

Table 3
Results of 2-way ANOVA testing for differences the abundances of taxonomic groups and their main representatives species between times (Ti) and seagrass meadows (Lo). Selected species contributing more than 2% of total abundance in any sample.

Mysidacea	Factor	df	MS	F	P	Decapoda	MS	F	P	Amphipoda	MS	F	P
Ti=time	Fixed	1	240.18	10.15	0.006*		22.30	9.48	0.034*		70.30	60.88	0.004*
Lo=location	Random	4	35.36	2.54	0.049*		9.14	6.72	0.002*		2.70	2.61	0.061
Ti × Lo		4	23.66	1.70	0.163		2.35	1.73	0.172		1.16	1.12	0.371
Residual		30	13.93				1.36				1.03		
Total		39											
S. armata	Factor	df	MS	F	P	*L. fucorum*	MS	F	P	*A. vexatrix*	MS	F	P
Ti=time	Fixed	1	28.86	1.08	0.446		1.08	0.79	0.38		41.31	59.29	0.005*
Lo=location	Random	4	26.80	2.42	0.091		1.32	5.61	0.002*		0.60	2.35	0.085
Ti × Lo		4	26.80	2.42	0.066		1.38	1.22	0.36		0.70	2.73	0.053
Residual		30	11.06				1.13				0.26		
Total		39											
L. lingvura	Factor	df	MS	F	P	*Hippolyte*	MS	F	P	*Dexamine*	MS	F	P
Ti=time	Fixed	1	0.10	0.62	0.715		38.56	25.21	0.006*		3.43	3.81	0.073
Lo=location	Random	4	0.09	0.58	1.000		3.37	5.59	0.002*		0.88	1.50	0.217
Ti × Lo		4	0.16	1.08	0.588		1.53	2.53	0.54		0.90	1.53	0.191
Residual		30					0.60				0.59		
Total		39											
Leptomyis spp.	Factor	df	MS	F	P	*Philocheras*	MS	F	P	*Ericthonius punctatus*	MS	F	P
Ti=time	Fixed	1	17.25	1.42	0.171		0.08	0.55	0.730		0.66	3.21	0.171
Lo=location	Random	4	12.12	2.28	0.081		0.07	0.55	1.000		0.21	1.54	0.223
Ti × Lo		4	12.12	2.28	0.073		0.14	1.10	0.574		0.21	1.54	0.217
Residual		30	5.31				0.13				6.34		
Total		39											

P. arenosa		Factor		df		MS		F		P
Ti=time		Fixed		1		2.82		1.68		0.165
Lo=location		Random		4		1.69		1.75		0.023*
Ti × Lo				4		1.69		1.75		0.022*
Residual				30		0.96				
Total				39						
G. roscoffensis		Factor		df		MS		F		P
Ti=time		Fixed		1		9.60		1.15		0.338
Lo=location		Random		4		10.31		4.34		0.002*
Ti × Lo				4		8.37		3.52		0.006*
Residual				30		2.38				
Total				39						
A. agilis		Factor		df		MS		F		P
Ti=time		Fixed		1		5.89		11.51		0.042*
Lo=location		Random		4		0.51		0.76		0.577
Ti × Lo				4		0.51		0.76		0.546
Residual				30		0.67				
Total				39						

* Significant differences for $P \leq 0.05$.

approach may have underestimated the number of suprabenthic mysids.

A total of six mysids species were identified, number similar that captured in seagrasses meadows from the Mediterranean Sea by Barberá-Cebrián et al. (2002) and Sánchez-Jerez and Esplá (1996). *S. armata*, *A. agilis*, *Leptomysis* sp., *L. lingvura* and *P. arenosa* have been previously recorded in *Cymodocea* meadows by Barberá-Cebrián et al. (2002) and Wittmann and Wirtz (1998).

Mysidacea is a major taxa of suprabenthic assemblages associated with seagrass meadows at temperate coastal waters (Mauchline, 1980; Yamada et al., 2007). During late spring, mysids were the most abundant organisms with abundances up to 200 ind m^{-3}, due to the large numbers of *S. armata* and *G. roscoffensis*. This highlights the importance of mysids in *C. nodosa* habitats. In the Canary Islands, during summer and spring, the shoot density and biomass of *C. nodosa* reaches its maximum (Tuya et al., 2006) and provides a nursery habitat for nearshore fishes, many of them with commercial interest

(Espino et al., 2011a). This period coincides with the maximum abundance of mysids, which could indicate a trophic relationship between juvenile fishes and mysids. The studies of Castro (1995) and Castro and Santana del Pino (1995) provide evidence of the importance of mysids as fish food in Gran Canaria; they were more abundant in the stomach content of *Scomber colias* than euphausiids. It is probable that chub mackerel feed closer to the shore where swarms of mysids are more accessible. Some of the mysids identified in the stomach content of chub mackerel (*Paramysis* sp., *Siriella* sp., *Anchialina agilis* and *Leptomysis* sp.) were found in *Cymodocea* meadows in the present study.

Other studies have also reported mysid peak abundances in spring (Tattersall, 1938; Mauchline, 1967, 1970, 1971; Mees et al., 1993a; San Vicente and Sorbe, 1993, 2003; Rappé et al., 2011). Spring peaks may be triggered by changes in some environmental factors such as temperature, salinity, turbidity, light or dissolved oxygen (Mauchline, 1980). The study area has a reduced annual
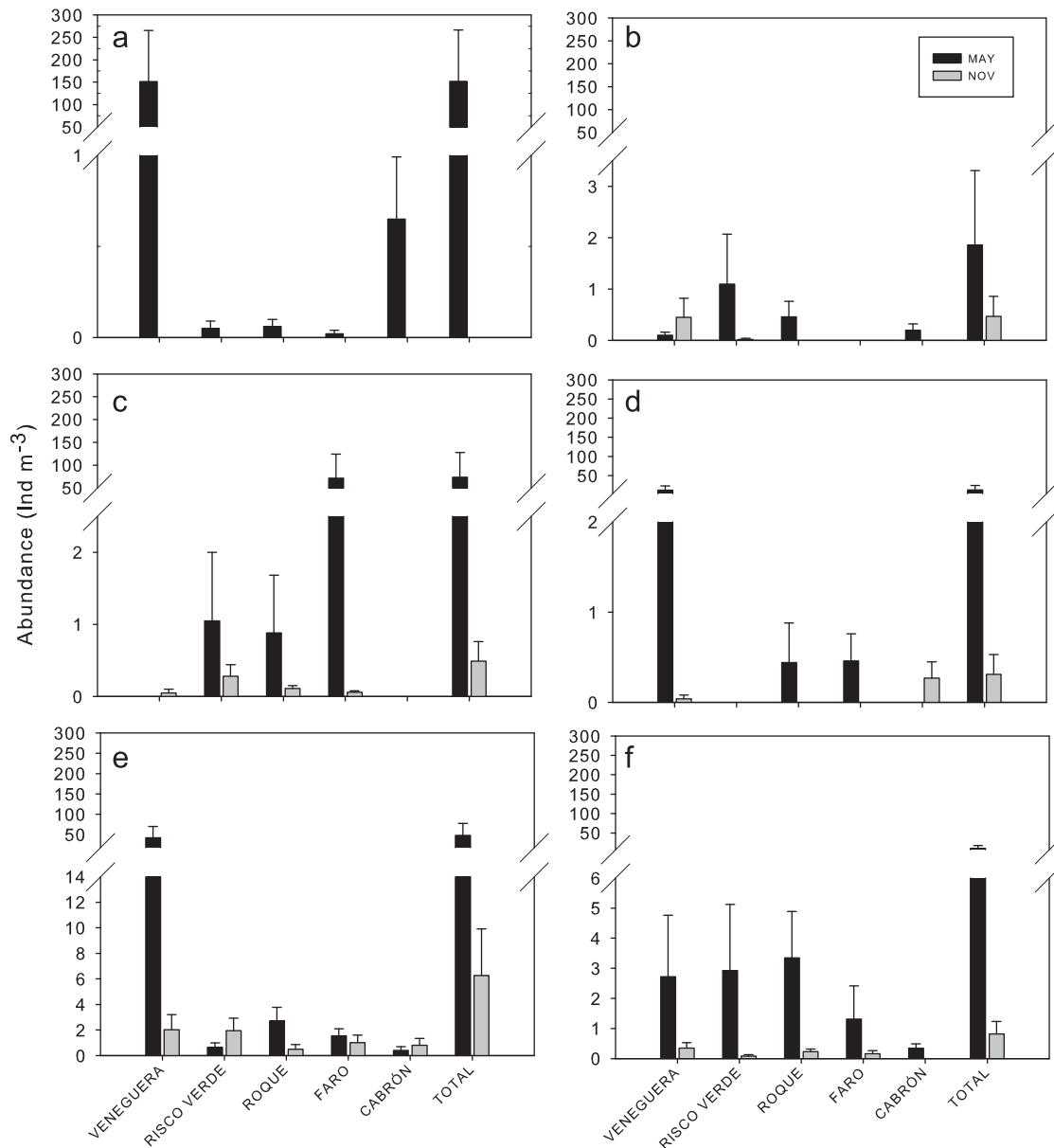
Fig. 5. Abundance (individuals m^{-3}) of mysids at spring (black bars) and autumn (gray bars). Error bars are $\pm$ SE of means.

variation of temperature (18–24 °C), salinity (35–36 PSU) and dissolved oxygen. With respect to light availability, PAR varies from 378 μmol m^{-2} s^{-1} in late spring to 174 μmol m^{-2} s^{-1} in late autumn on a seagrass meadow at 8 m depth (see Table 1, Fig. 2). This is the main factor influencing the vitality of *C. nodosa* through seasons in the study region (Tuya et al., 2006, 2014). As a result, seasonal changes in *Cymodocea nodosa* shoot density, leaf length and plant cover, triggered by light availability, may help out to explain seasonal patterns in mysid abundance better than other environmental factors or processes.

This seasonal pattern could be also explained by seasonal onshore–offshore migrations (Jumars, 2007). A number of onshore–offshore migrators show winter maxima offshore, but from spring to fall they occur in high abundances on shallower waters and even inside estuaries (Mauchline, 1980). In Gran Canaria, mysids have been majorly overlooked by most zooplankton sampling programs (Hernández-León, 1988; Gómez and Hernández-León, 1997). However, their importance was pointed out by a study of the stomach contents in the abundant coastal fish *Scomber colias* (Castro, 1995). This study showed a peak in mysid

abundance per fish during December and a minimum from January to April. Here, *A. agilis* showed an abundance peak in May on shallow waters, and reached its maximum abundance in the stomach of *Scomber colias* in offshore waters in December (Castro, 1995; Castro and Santana del Pino, 1995).

The present study has shown that many mysids, such as *S. armata*, *L. lingvura*, *Leptomysis* sp. and *P. arenosa*, aggregate in swarms (SCUBA observations). Mysid aggregation has been described previously for several mysid species (Clutter, 1969; Mauchline and Murano, 1977; Wittmann et al., 1977; San Vicente and Sorbe, 2003). This behavior helps to explain the high variability between replicates at each locality and the difficulty to detect significant seasonal changes in the abundance of these species. This was not the case for *A. agilis*, probably because this species does not aggregate in swarms (SCUBA observations) (Wittmann et al., 1977).

Finally, we conclude that the natural cycle of *Cymodocea* seems to determine the structure and density of associated suprabenthic assemblages. By taking into consideration the decline of *C. nodosa* meadows around Gran Canaria over the last two decades (Tuya et al., 2013, 2014) the associated suprabenthos may have been
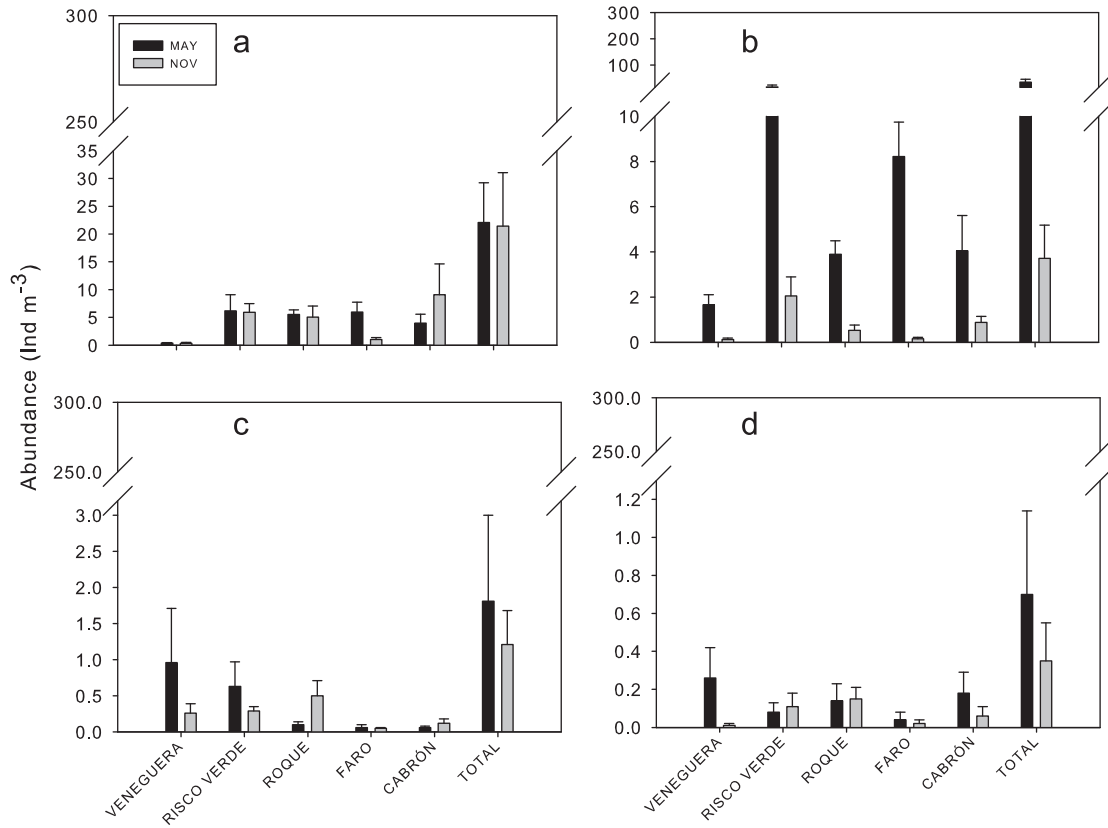
Fig. 6. Abundance (individuals m^{-3}) of the main decapods at spring (black bars) and autumn (gray bars). Error bars are $\pm$ SE of means.
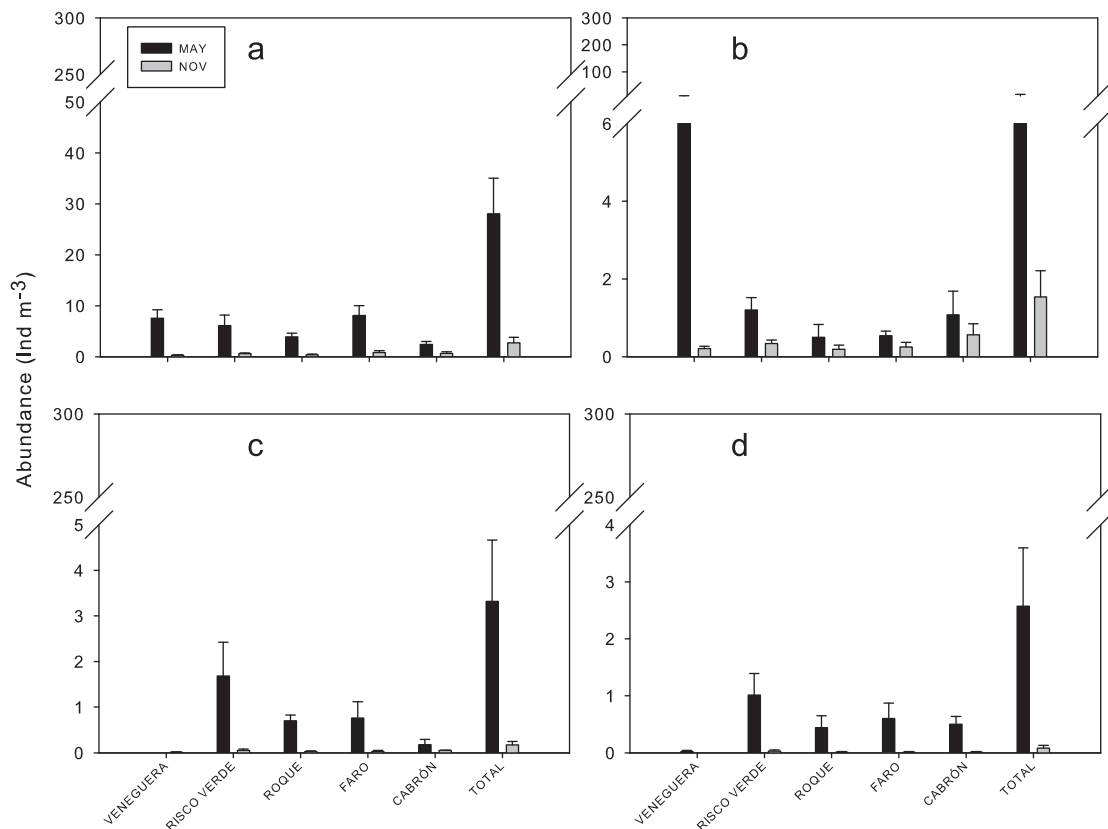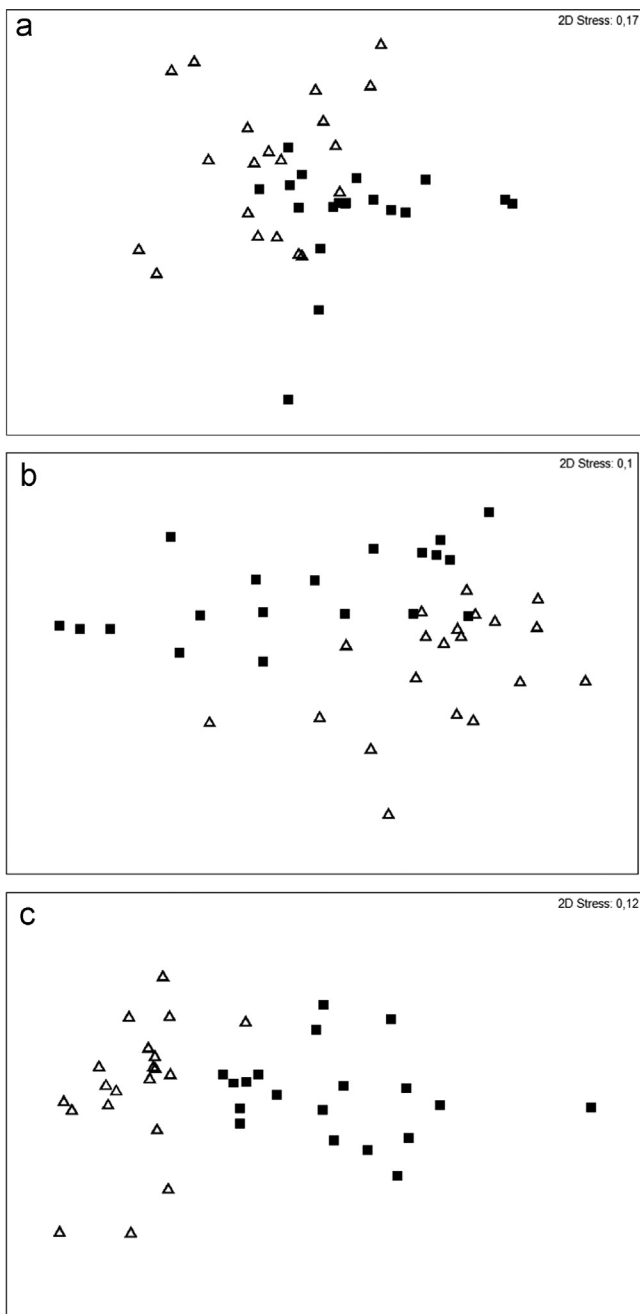

Fig. 7. Abundance (individuals m^{-3}) of the main amphipods at spring (black bars) and autumn (gray bars). Error bars are $\pm$ SE of means.

Fig. 8. Multidimensional Scaling (MDS) ordination plot of the structure of: (a) mysid, (b) amphipod, and (c) decapod assemblages. Triangles: May 2011; squares: November 2011.

seriously impacted. Further studies are required to determine the extent of this impact and to design adequate conservation programmes.

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