PYCNOGONIDS (ARTHROPODA: PYCNOGONIDA) IN SEAGRASS MEADOWS: THE CASE OF O GROVE INLET (NW IBERIAN PENINSULA)

PATERICIA ESQUETE (1*), ROGER N. BAMBER (2), JUAN MOREIRA (3) & JESÚS S. TRONCOSO (1)

(1) Departamento de Ecología y Biología Animal, Facultad de Ciencias del Mar, Universidad de Vigo, E-36310 Vigo, Pontevedra, Spain.
(2) ARTOO Marine Biology Consultants, Ocean Quay Marina, Belvidere Road, Southampton SO14 5QY, UK.
(3) Departamento de Biología (Zoología), Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain.
*Corresponding author: pesquete@uvigo.es

ABSTRACT

Quantitative studies dealing with the ecology of the Pycnogonida (Arthropoda) are scarce. In this work, the pycnogonid fauna present in the seagrass meadows (Zostera spp.) of an estuarine environment in NW Spain are studied, including spatial distribution and intra-annual seasonal variations of density and diversity. Quantitative sampling showed that the pycnogonid taxocoenosis associated with seagrass meadows was rich and diverse. The best represented species in terms of distribution and abundance were Callipallene tiberi, Achelia echinata and Anoplodactylus pygmaeus. Abundances showed a strongly seasonal pattern, with the highest values in September and lowest in March. Temporal variations in the population dynamics of A. echinata suggest a strong coupling with the life story of the seagrass Zostera marina, which in turn determines the availability of food resources for the pycnogonid assemblage.

Key words: Pycnogonida, diversity, distribution, seagrass, Atlantic Ocean.

RESUMEN (Picolgónidos en praderas de fanerógamas marinas: El caso de la ensenada de O Grove (NO de la Península Ibérica)

Hasta la fecha, son escasos los estudios cuantitativos que han tratado la ecología de la clase Pycnogonida (Arthropoda). En este trabajo, la fauna de pycnogónidos presente en las praderas de fanerógamas (Zostera spp.) en un ambiente estuarino del noroeste de España, incluyendo su distribución espacial y las variaciones estacionales de densidad y diversidad. Los datos cuantitativos obtenidos muestran que la taxocenosis de picnogónidos asociada a las fanerógamas es rica y diversa. Las especies mejor representadas en términos de distribución espacial y abundancia fueron Callipallene tiberi, Achelia echinata y Anoplodactylus pygmaeus. Los valores de abundancia mostraron un patrón fuertemente estacional, con los mayores registros en el mes de Septiembre y los más bajos en Marzo. Las variaciones de abundancia en la población de A. echinata sugieren un patente acoplamiento con el ciclo vital de Zostera marina, que a su vez determina la disponibilidad de recursos alimentarios para los pycnogónidos.

Palabras clave: Pycnogonida, diversidad, distribución, fanerógamas marinas, Océano Atlántico.
Figure 1: Location of O Grove inlet and the sampling sites.
INTRODUCTION

The class Pycnogonida is an exclusively marine group of arthropods also known as “sea spiders”, with no clear affinities to any other group and considered either as a sister group to the Eurhacicerata or as the sister group to all extant rest of the Euarthropoda (Bamber, 2007; 2010; Arango and Wheeler, 2007). Pycnogonids are predominantly benthic, slow-moving organisms, and feed mainly on sessile prey such as algae, hydroids, actinarians and bryozoans (Wyler and King, 1974; Bamber and Davis, 1982); generally, their abundances depend on the availability of food resources (Roberts, 1981; Arnaud and Bamber, 1987). Other factors such as salinity gradients (Wolff, 1976) and hydrodynamics (Munilla León and San Vicente, 2000) have also been reported to influence their local abundance and distribution.

Quantitative studies dealing with the ecology of pycnogonids are scarce (but see Wolff, 1976; Munilla, 1981; 1991; Arnaud and Bamber, 1987 and references therein; Sánchez and Munilla, 1989; Pérez-Ruzafa and Munilla, 1992; Munilla and Nieto, 1999; Genzano, 2002; Soler i Membrives et al., 2009). In fact, most of the data available for tropical and temperate areas come from wider studies on benthic community ecology where pycnogonids are rarely found in high numbers; these data usually do not allow a reliable characterization of patterns in their environmental needs, ecological role or population dynamics.

Seagrass meadows constitute complex habitats and are considered as “ecosystem engineers” because they favour the settlement and maintenance of high benthic species diversity in temperate and tropical waters (Montadouin and Sauriau, 2000; Hasegawa et al., 2008) including that of pycnogonids (Arnaud and Bamber, 1987; Chimenz et al., 1993). In the Iberian Peninsula, some data on pycnogonids occurring in seagrass beds in the Mediterranean Sea are provided by De Haro (2007; 2010). The body length of specimens was measured in 70% ethanol. Specimens were measured using a stereomicroscope fitted with a micrometer eyepiece.

In this work, the composition and diversity of the pycnogonid assemblage present in the seagrass meadows (Zostera marina L. and Z. noltii Hornem.) of an estuarine environment (O Grove inlet, NW Spain) is studied quantitatively on a spatial and temporal scale. In particular, the dynamics and structure of a population of Achelia echinata is investigated from the data obtained and related to the presence and the life history of the seagrasses.

MATERIAL AND METHODS

The O Grove inlet is an estuarine environment situated in the northwest coast of the Iberian Peninsula between 42°41′ –42°28′N and 09°01′ –08°44′W (Figure 1). Most of its intertidal and shallow subtidal sediments are covered by meadows of Zostera marina and Z. noltii. The area is subjected to seasonal freshwater inputs from several streams and a high level of precipitation in autumn/winter.

In December 1996, benthic samples were taken with the aim of characterizing the spatial distribution of the macrofaunal assemblages present in the meadows. Five replicate samples were taken from each of ten sites by means of a van Veen grab covering a total area of 0.28 m² for each site (Table 1; Figure 1); additional details on location and abiotic features of the sampling sites may be found in Esquete et al. (2010). A sample of the bottom water was taken by means of a Niskin bottle and salinity, temperature and pH were measured in situ.

In addition, temporal samples were taken bimonthly between May 1998 and March 1999 at a subtidal Z. marina meadow (corresponding to site 3; see Table 1) to study the seasonal dynamics of the fauna. This site was selected for the good state of conservation of the Zostera meadow; furthermore, it was assumed that it would be less affected by salinity fluctuations than meadows situated in more sheltered areas. For this study, samples were taken by SCUBA divers, collecting five replicate quadrats of 25 x 25 cm (0.065 m²) in each occasion. The shoot and the rhizome fractions of the seagrass (the latter including the sediment) were kept separately in plastic bags and their fauna sorted separately. Abiotic parameters were measured following the same methodology as in the previous phase.

For both studies, samples were sieved through a 0.5 mm mesh and fixed in 10% buffered formalin. Specimens were later sorted, identified, and preserved in 70% ethanol. Specimens were measured using a stereomicroscope fitted with a micrometer eyepiece.

Pycnogonid classification follows that used by Bamber (2007; 2010). The body length of specimens was measured from the anterior margin of the cephalon to the posterior margin of the last lateral processes.
RESULTS

Spatial study

A total of 232 individuals belonging to 9 species was found in 9 out of 10 sampling sites in December 1996 (Table 1). The most abundant species was *Callipallene tiberi* (Dohrn, 1881) (85 individuals, 36.6% of total abundance) followed by *Achelia echinata* Hodge, 1864 (72 indiv., 31.0% of total abundance) and *Anoplodactylus pygmaeus* (Hodge, 1864) (57 indiv., 24.6% of total abundance). These three species accounted for the 91% of the total pycnogonid abundance. The most widespread species in the inlet was *A. pygmaeus* (present in 8 out of 10 sites), followed by *C. tiberi* (7 sites).

Temporal study

During the studied period, 297 individuals belonging to 7 species were found (Table 2). *Achelia echinata* was by far the numerically dominant species, accounting for 72.1% of total abundance (214 individuals), followed by *Anoplodactylus pygmaeus* (13.1% of total abundance, 39 indiv.). The maximal values of number of species and of individuals were obtained in September (88 individuals, 7 species); the lowest abundance was recorded in May (26 indiv.). *Achelia echinata* was present on all sampling occasions (6) followed by *A. pygmaeus*, *C. tiberi* and *N. gracile* (5 each).

SYSTEMATICS

**Class Pycnogonida** Latreille, 1810
**Family Ammotheidae** Dohrn, 1881
**Genus Achelia** Hodge, 1864
*Achelia echinata* Hodge, 1864

Material examined.- Spatial study (December 1996): 6 ♀♀, site 1; 12 ♀♀, 23 ♂♂, 2 juveniles, site 3; 4 ♀♀, 3 ♂♂, 3 juveniles, site 4; 3 ♂♂, site 6; 7 ♂♂, site 7; 1 ♀, 1 ♂, site 8; 4 ♀♀, 1 ♂, 1 juvenile, site 9. Temporal study (site 3): 7 ♀♀, 2 ♂♂, 8 juveniles, May 1998; 5 ♀♀, 4 ♂♂, 13 juveniles, July 1998; 18 ♀♀, 13 ♂♂, 32 juveniles, September 1998; 11 ♀♀, 9 ♂♂, 21 juveniles, November 1998; 16 ♀♀, 8 ♂♂, 10 juveniles, January 1999; 15 ♀♀, 9 ♂♂ (5 ovigerous), 1 juvenile, March 1999.

Body size.- ♀♀: 0.5-2 mm; ♂♂: 0.6-1.1 mm; juveniles: 0.3-0.9 mm.

Distribution.- Widely distributed in the Atlantic and Mediterranean Sea, including around the Iberian coasts (De Haro, 1965; Munilla, 1987).

Remarks.- *Achelia echinata* is a common, abundant and widespread species in the north Atlantic. In the Zostera meadows of O Grove, this species was very abundant, particularly in the subtidal meadow corresponding to site 3 (Tables 1, 2). The temporal study at this site provided enough individuals to allow the examination of the population dynamics of this species. There was an increase in the number of individuals from spring through summer, reaching a maximum in September and declining through autumn and winter until the following spring. The highest proportion and numbers of juveniles were found in July, decreasing to a minimum in March (Figure 2). Gravid females were found throughout the year, although in small numbers (1-5 per sample); five ovigerous males were found in March.

**Family Nymphonidae** Wilson, 1878
**Genus Nymphon** Fabricius, 1794
*Nymphon gracile* Leach, 1814


Body size.- 1.8-4.5 mm. ♀ with eggs 4.6 mm.


Remarks.- In March 1999, one male was found carrying four egg masses.

**Family Callipallenidae** Hilton, 1942
**Genus Callipallene** Flynn, 1929
*Callipallene brevirostris* (Johnston, 1837)

Material examined.- Spatial study (December 1996): 1 ♂, 1.0 mm, site 5.


*Callipallene emaciata* (Dohrn, 1881)

Material examined.- Spatial study (December 1996): 3 ♀♀, site 5; 3 ♀♀, site 9; 1 ♀, 2 juveniles, site 10. Temporal study (site 3): 1 ♂, 1 ♀, 1 juvenile, September 1998; 1 juvenile, November 1998; 5 ♀♀, January 1999.

Body size.- ♀♀ 0.8-1.1 mm; ♂♂ 1.2 mm; juveniles 0.6 mm.
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**Callipallene spectrum** (Dohrn, 1881)

Material examined.- Spatial study (December 1996): 1 ♀, 1 ♂, site 5; 1 ♀, 1 ♂, site 8. Temporal study (site 3): 1 ♀, 2 ♀♀, September 1998; 1 ♂, 3 ♀♀, November 1998.

Body size.- ♀♀ 0.9-1.2 mm; ♂♂ 1.0-1.2 mm.

Distribution.- South of Great Britain, Atlantic coast of Spain, Mediterranean Sea (De Haro, 1965; Munilla, 1993).

**Callipallene tiberi** (Dohrn, 1881)

Material examined.- Spatial study (December 1996): 9 ♀♀, 1 ♂, site 3; 2 ♀♀, site 4; 35 ♀♀, 4 ♂♂, 1 juvenile, site 5; 1 ♀, site 6; 13 ♀♀, 1 ♂, site 8; 6 ♀♀, 1 ♂, 3 juveniles, site 9; 7 ♀♀, 1 ♂, site 10. Temporal study (site 3): 1 ♀, 1 ♂, 2 juveniles, May 1998; 1 ♂, July 1998; 2 ♀♀, September 1998; 1 ♀, November 1998; 2 ♀♀, 1 ♂, March 1999.

Body size.- ♀♀ 0.8-1.3 mm; ♂♂ 1-1.2 mm; juveniles 0.6-0.7 mm.


Family PHOXICHILIDIDAE Sars, 1891

Genus Anoplodactylus Wilson, 1878

**Anoplodactylus petiolatus** (Hodge, 1864)

Material examined.- Spatial study (December 1996): 2 ♀♀, 1 mm, site 1.

Distribution.- Widely distributed from western to eastern Atlantic, Mediterranean and Black seas. Iberian Peninsula: Cantabrian coast (Munilla, 1987), Galician Rias (Moreira and Troncoso, 2007), SE Iberian Peninsula, Gibraltar Strait (Munilla, 1993), Mediterranean coast (De Haro, 1967).

**Anoplodactylus pygmaeus** (Hodge, 1864)

Material examined.- Spatial study (December 1996): 3 ♀♀, 1 ♂, 1 juvenile, site 1; 3 ♀♀, 4 ♂♂, site 3; 6 ♀♀, site 4; 1 ♀, 4 ♂♂, site 5; 13 ♀♀, 9 ♂♂, site 6; 1 ♀, 1 ♂, site 7; 2 ♀♀, site 8; 5 ♀♀, 1 ♂, 1 juvenile, site 9; 1 ♂, site 10. Temporal study (site 3): 4 ♀♀, 1 ♂, 1 juvenile, May 1998; 8 ♀♀, 3 ♂♂, 2 juveniles, September 1998; 4 ♀♀, 2 ♂♂.

Figure 2: Abundance (individuals/0.312 m²) of juveniles, adult females and adult males of Achelia echinata in site 3 from May 1998 to March 1999.
(1 ovigerous), 1 juvenile, November 1998; 5 ♀♀, 5 ♂♂, 1 juvenile, January 1999; 2 ♀♀, March 1999.

**Body size.** ♀♀ 0.6-0.8 mm; ♂♂ 0.7 mm.


**Remarks.** One ovigerous male was found in September 1998.

**Family ENDEIDAE Norman, 1908**

**Genus Endeis Philippi, 1843**

**Endeis spinosa** (Montagu, 1808)


**Body size.** ♀♀ 1.8-2.2 mm; ♂♂ 2.3 mm.

**Distribution.** Widespread Amphiatlantic species. Iberian Peninsula: Cantabrian Coast (Munilla, 1987), Ría de Vigo (Anadón, 1975), Gibraltar (Munilla, 1993), Mediterranean coast (De Haro, 1965).

**Remarks.** One specimen collected in July 1998 presented one leg of the third pair abnormally small, about ¼ of the normal length.

**DISCUSSION**

The pycnogonid taxocoenosis found in the *Zostera* meadows of the O Grove inlet comprises species typical of European shallow environments (Arnaud and Bamber, 1987). The studied *Zostera* meadows have a richer pycnogonid fauna than those present in other shallow habitats and sedimentary substrata in the Galician rías. For example, Moreira and Troncoso (2007) and Cacabelos et al. (2009), using an identical methodology, only found two and four pycnogonid species in nearby inlets, respectively, and in much lower numbers. Likewise, extensive studies carried out in other European areas with salinity fluctuations have reported similar assemblages to those found in O Grove, but characterized by lower densities for most of the species (Wolff, 1976; Pérez-Ruzafa and Munilla, 1992, excepting *Tanystylum conirostre* (Dohrn, 1881)). In general, hard substrata with seaweed biocoenoses host more diverse assemblages (e.g. Munilla, 1991; Chimenz et al., 1993) than unvegetated sedimentary bottoms which tend to be poor in pycnogonid faunas (Chimenz and Cotarelli, 1986; Pérez Ruzafa and Munilla, 1992; Chimenz et al., 1993). However, most studies point out that pycnogonids are well represented in soft bottoms when covered by *Posidonia oceanica* (e.g. De Haro, 1967; Arnaud, 1988; Chimenz et al., 1993; Munilla León and San Vicente, 2000). Moreover, those have also been proposed as a “source” habitat for pycnogonids to colonise adjacent habitats (Munilla and San Vicente, 2000).

**Table 1:**

| Pycnogonid species found at ten sites (1 to 10) in the O Grove inlet in December 1996 showing densities per site (individuals/0.28 m²), total abundance, numerical dominance (D, %), seagrass species (Z. marina: M; Z. noltii: N) and values of selected environmental variables of seawater. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Achelia echinata | 6 | 37 | 11 | - | 3 | 7 | 2 | 6 | - | 72 | 31.0 |
| Nympnhe gracile | - | - | 1 | - | - | - | - | - | - | 1 | 0.4 |
| Callipallene brevirostris | - | - | - | 1 | - | - | - | - | - | 1 | 0.4 |
| Callipallene emaciate | - | - | - | 3 | - | - | - | - | 3 | 3 | 9 | 3.9 |
| Callipallene spectrum | - | - | 2 | - | - | - | - | - | 2 | - | 4 | 1.7 |
| Callipallene tiberi | - | 10 | 2 | 40 | 1 | - | 14 | 10 | 8 | 85 | 36.6 |
| Anoplodactylus petiolates | 2 | - | - | - | - | - | - | - | - | - | 2 | 0.9 |
| Anoplodactylus pygmaeus | 5 | 7 | 6 | 5 | 22 | 2 | 2 | 7 | - | 57 | 24.6 |
| Endeis spinosa | 1 | - | - | - | - | - | - | - | - | 1 | 0.4 |

| Number of species | 4 | 3 | 4 | 5 | 3 | 2 | 4 | 4 | 2 | 9 |
| Total abundance | 14 | 54 | 20 | 51 | 26 | 9 | 20 | 26 | 12 | 232 |

| Seagrass | M | M | M | M/N | N | N | M/N | M/N | M/N |
| Depth (m) | 0.6 | 5.9 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| pH | 7.7 | 7.8 | 7.8 | 7.7 | 7.9 | 7.7 | 7.7 | 7.7 | 7.7 |
| Temperature (ºC) | 14.6 | 9.9 | 16.7 | 13.0 | 15.3 | 13.2 | 13.2 | 13.0 | 13.3 |
| Salinity (‰) | 29.0 | 32.0 | 32.5 | 30.0 | 30.5 | 20.0 | 33.0 | 33.0 | 32.0 |
The abundance of pycnogonids in O Grove showed great seasonal fluctuations, with the highest numbers of species and individuals in September and the lowest values in spring. Particularly, in the case of *A. echinata*, the highest numbers and proportion of juveniles occurred in July, followed by a substantial increase of the total abundance of the population in September. This indicates a high rate of survival of juveniles during the summer. Likewise, the population decreased in the following sampling periods coupled with a high number of juveniles; this suggests, on the one hand, low rates of survival of adults in autumn and, in the other hand, an ongoing recruitment of juveniles through autumn. In winter-spring, the population reaches the minimum in total numbers and percentage of juveniles, suggesting that the conditions are not favourable for reproduction and survival. These results are similar to those found by Jarvis and King (1978), who pointed out that juvenile stages of *A. echinata* appear in April and reach a maximum in August. In contrast, Munilla León (1980) found a maximum of juveniles in April, and minimum values in August-September, and suggested that such differences between different populations of the same species are due to variations in environmental conditions.

The temporal dynamics of *A. echinata* in particular (Figure 2) and that of the whole pycnogonid taxocoenosis in general (Table 2) seems to be coupled with the life cycle of *Z. marina*: thus, the seagrass shows elongation of leaves and rhizomes in spring-summer and dispersion of seeds in winter (Hasegawa et al., 2007). This coincidence of the maximal values of pycnogonid density and those of the above-ground biomass of the seagrass can be explained by the subsequent increase of surface available for epiphytic algae, hydroids and bryozoans that occurs when leaves are enlarged; these epiphytes, which bloom in August, provide a significant increase in food resources (Böstrom et al., 2006; Hasegawa et al., *opus cit.*) from which the populations of pycnogonids may benefit, therefore reaching their greatest abundances after late summer. Similarly, the highest proportions and numbers of juvenile stages coincide with this bloom of epiphytes, suggesting that the reproductive period occurs in the months previous to the maximum of food availability. Seasonal variations in abundances of secondary producers in seagrass meadows, linked to the life history of the plant and abundance of epiphytic food-species has been verified for a number of benthic taxa (e. g. Edgar, 1990; Böstrom et al., 2006). Indeed, previous studies in the O Grove meadows have also shown similar fluctuations for gastropods, bivalves and several polychaete families (Quintas, 2005), isopods and amphipods (Esquete et al., 2011).

In conclusion, the present study suggests that the presence of the seagrass favours the availability of food resources for pycnogonids, thereby allowing a higher diversity than in other non-vegetated habitats. Similarly, the seasonal evolution of the *Zostera* meadow would entirely determine the seasonal variations in diversity and abundance of the pycnogonids.
ACKNOWLEDGEMENTS

The authors are grateful to the members of the Adaptaciones de Animales Marinos group (Universidade de Vigo) for their help with sampling collection and especially to P. Quintas for the sorting of samples. This work was supported by the Xunta de Galicia (grant number XUGA 30101A98). Constructive comments from two anonymous referees are acknowledged.

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(Received: September 14, 2012; Accepted: October 30, 2012)