Introduction

Astroides calycularis (Pallas, 1766) is an azooxanthellate colonial scleractinian, with a calcium carbonate exo-skeleton (Zibrowius, 1980) that inhabits the rocky shores from the surface to a depth of 50 m (Rossi, 1971). It occupies both well-lit and dark habitats and appears to prefer environments with strong currents (Zibrowius, 1978; 1995; Kružic et al., 2002). Its population density can be locally high, with colonies covering up to 90% of the sea bottom (Goffredo et al., 2011). Populations of A. calycularis mainly have a limited geographical distribution in the Mediterranean Sea, restricted to the south-western area (Zibrowius, 1980; 1995; Bianchi, 2007). Though, the species has been also quoted in Adriatic Sea (Grubelj et al., 2004). Andalusian rocky shores (southern Iberian Peninsula) host one of the highest densities of the orange coral populations (Terrón-Sigler et al., 2015).

Terrón-Sigler et al. (2014) observed that peracarid crustaceans were the most prevalent species associated with the orange coral. Additionally, three of the peracarids associated with A. calycularis had a strong orange colour (i.e. Janira maculosa, Sthenothoe cavimana, and Caprella penantis) (Terrón-Sigler et al., 2014). However, the nature of the association is unclear, whether it is obligate or facultative, and whether the coral is used as a substrate (e.g. refuge, spawning, brood care or protection by crypsis) or as a feeding source (partial or totally).

Amphipods are the most diverse group of crustaceans in terms of lifestyle, trophic types and habitats (De Broyer & Jazdzewski, 1996). Due to their population’s characteristics, amphipods may play major roles in the ecology of their habitats (Conlan, 1994). Amphipods are known to have versatile feeding strategies (i.e. Sarvala & Uitto, 1991) and show a wide range of feeding habits (Conradi & Cervera, 1995). They also constitute an important food source for a large variety of marine predators (Vázquez-Luis et al., 2013); hence playing a key role in energy flow through food webs (Guerra-García et al., 2014). Consequently, the main objective of the present study is to explore if peracarids associated with A. calycularis feed on the host coral’s tissues, in an effort to highlight the nature of the association.

Material and Methods

161 specimens of peracarids were collected from 23 colonies of A. calycularis from Marina del Este beach (Granada coast; Andalusia; Spain) in July 2011 (Figure 1). Colonies were covered in situ with plastic bags before they were removed in order to keep all the associated fauna. The samples were fixed in 4% formalin and subsequently placed in 70% ethanol in the laboratory. The colonies were washed, the macrofauna sieved using a 0.5 mm size mesh, and the specimens collected were sorted and identified at the species level, when possible.

Diet study was analysed following the methodology proposed by Bello & Cabrera (1999) with slight variations. Recently, this method was successfully used in amphipods (i.e. Navarro-Barranco et al., 2013; Vázquez-Luis et al., 2013; Guerra-García et al., 2014).
Specimens of each species were introduced in vials with Hertwig’s liquid (consisting of 270 g of chloral hydrate, 19 ml of chloridric acid 1 N, 150 ml of distilled water and 60 ml of glycerine) and oven-heated at 65 °C for 4 to 6 hours depending on the cuticle thickness of the specimens. After this, samples were mounted on slides for microscope study. The percentage of absolute gut content (i.e. total area occupied by the content in the whole digestive tract) and the relative gut content (i.e. area occupied by each component within the total gut content) were estimated using a microscope equipped with an ocular micrometer (at 40× or 100×). Mean and standard error of the mean were calculated.

**Results and Discussion**

The collected peracarid specimens belonged to 11 species and distributed in 9 families (Table 1), representing the dominant peracarids associated with *Astroides calycularis* in the south Iberian Peninsula. Gut contents of the studied amphipod species included detritus, crustaceans and macroalgae (Table 1). The dominant component was detritus, followed by crustacean pieces and macroalgal tissues. In a diet analysis of marine amphipods around the Iberian Peninsula, Guerra-García et al. (2014) concluded that detritivorous species had fuller guts than carnivorous species, where empty guts predominated. Nevertheless, trophic classifications may be subjective. In our study, three species namely *Liljeborgia psaltrica*, *S. cavimana* and *Eusirodides dellavallei*, presented empty guts. Although, these three species might be considered carnivorous, the amphipods associated with *A. calycularis* colonies presented the majority of the gut content occupied by detritus, highlighting the importance of detritus for the amphipods already noted in the Iberian Peninsula by Guerra-García et al. (2014).

Gut content ranged from 16% in *Leucothoe spinicarpa* to 64.3% in *J. maculosa*. In general, species with detritus had a higher area occupied by content in the digestive tract than other species.

Regarding caprellid species, these findings are in agreement with other studies, where the detritus was the dominant food source in seaweed-associated caprellids (Guerra-García & Tierno de Figueroa, 2009; Guerra-García et al., 2014). In the present study, the two caprellids collected from orange coral colonies showed more than 98% detritus composition in their gut contents.

There is scarce information about the feeding habits of marine isopods (e.g. Navarro-Barranco et al., 2013). In this study, *Paragnathia formica* showed 100% detritus gut content, while *J. maculosa* had a diverse gut content (Table 1).
Table 1. Gut contents of the studied peracarid species. N: number of specimens of each species examined, n: number of specimens with detected digestive contents. % Abs: total area occupied by the content in the whole digestive tract. Det: detritus, Crust: crustaceans, Malg: Macroalgae. Mean values with standard errors of the mean (in parentheses) are included.

<table>
<thead>
<tr>
<th>PERACARIDS</th>
<th>N/n</th>
<th>% Abs</th>
<th>% Det</th>
<th>% Crust</th>
<th>% Malg</th>
<th>Feeding group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isopods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Janira maculosa Leach, 1814</td>
<td>22/22</td>
<td>64.3 (19.1)</td>
<td>93.9 (8.6)</td>
<td>5.7 (3.1)</td>
<td>0.5</td>
<td>Omnivorous</td>
</tr>
<tr>
<td>Paragnathia formica Hesse, 1864</td>
<td>12/10</td>
<td>27.5 (15.5)</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>Detritivorous</td>
</tr>
<tr>
<td>Amphipods</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lembos sp. Bate, 1857</td>
<td>23/22</td>
<td>50.2 (30.7)</td>
<td>92.7 (6.3)</td>
<td>7.3 (5.2)</td>
<td>--</td>
<td>Omnivorous</td>
</tr>
<tr>
<td>Autonoe spiniventris Della Valle, 1893</td>
<td>9/8</td>
<td>59.4 (39)</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>Detritivorous</td>
</tr>
<tr>
<td>Leucothoe spinicarpa Abildgaard, 1789</td>
<td>19/17</td>
<td>16 (9.1)</td>
<td>98.1 (3.1)</td>
<td>1.9 (0.8)</td>
<td>--</td>
<td>Omnivorous</td>
</tr>
<tr>
<td>Liljeborgia psaltrica Krapp-Schickel, 1975</td>
<td>20/0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Carnivorous</td>
</tr>
<tr>
<td>Sthenothoe cavimana Chevreux, 1908</td>
<td>20/0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Carnivorous</td>
</tr>
<tr>
<td>Eucrioides dellavallei Chevreux, 1899</td>
<td>3/0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Carnivorous</td>
</tr>
<tr>
<td>Caprella acanthifera Leach, 1814</td>
<td>14/14</td>
<td>61.1 (3.7)</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>Detritivorous</td>
</tr>
<tr>
<td>Phitisca marina Slabber, 1769</td>
<td>11/8</td>
<td>19.4 (13.9)</td>
<td>98.7 (3.5)</td>
<td>1.3</td>
<td>--</td>
<td>Omnivorous</td>
</tr>
<tr>
<td>Tanais dulongii Audouin, 1826</td>
<td>8/7</td>
<td>55.7 (28.7)</td>
<td>98.8 (3.7)</td>
<td>1.2</td>
<td>--</td>
<td>Omnivorous</td>
</tr>
</tbody>
</table>

The tanaid Tanais dulongii associated with Fucus spiralis in the south Iberian peninsula is herbivorous with fucoid algae its primary diet source (Torrecilla-Roca & Guerra-García, 2012). The specimens associated with A. calycularis did not show this feeding habit; more than 98% of the gut content was detritus and the remaining was composed of crustacean fragments. This finding highlights the plasticity in the feeding habits of peracarid species depending on the host or habitat where they inhabit.

Scleractinian corals function as structural engineers (Jones et al., 1994), contributing to an increase in habitat complexity and surface topography, which promotes biodiversity by mediating competition or predation (Hixon & Menge, 1991; Coker et al., 2009). Corals provide a large surface area where invertebrate assemblages can live, as well as refuges from predator, food source in the form of coral tissue, mucus and its associated detritus, and a hard skeleton used as a substratum by specialized burrowers (Castro, 1988). Taking all these factors into account, the peracarids associated with A. calycularis might use the coral skeleton as a refuge against potential predators (by hiding or as crypsis) or as food source of detritus that the colonies generate. Commensalisms between amphipods and cnidarians has been documented worldwide (e.g. Vader & Krapp-Schickel, 1996; Esquete et al., 2014), but there is little information about this association with corals. Therefore, more studies are necessary in this regard with scleractinian corals. The analysis of gut contents of peracarids associated with the intertidal algae F. spiralis revealed that the assemblage is dominated by species feeding mainly on this algae (Torrecilla-Roca & Guerra-García, 2012), in contrast with other crustaceans inhabiting different seaweed assemblages which mainly feed on detritus (Guerra-García & Tierno de Figueroa, 2009; Alarcón-Ortega et al., 2012). This could highlight that, depending upon the host with which the peracarids are associated, the relationship could be host-dependent or not, but further research needs to be carried out in this regard.

Acknowledgements

Our research was supported by the Regional Government of Andalusia (General Office of Environment Management, Regional Ministry of Environment). We thank the General Office of Marine Protected Area from the Spanish state (National Ministry of Environment). Financial support for this work was provided by the Asociación Hombre y Territorio (http://www.hombreyterritorio.org) and the Laboratorio de Biología Marina (Departamento de Zoología, Facultad de Biología, Universidad de Sevilla). Special thanks to our colleague J. M. Guerra-García for his assistance with laboratory methods and taxonomic identifications, and Manuel González O’Sullivan and Paul Worrall for their assistance during the English review process. The experiments complied with current Spanish laws.

References


bleaching and habitat degradation increase susceptibility to predation for coral-dwelling fishes. *Behavioral Ecology*, 20, 1204-1210.


