Euphausiids (Crustacea: Euphausiacea) from a hotspot of marine biodiversity, Isla del Coco, Costa Rica, Eastern Tropical Pacific

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Abstract: Euphausiids have been well studied in several regions of the Pacific Ocean; however, there is less information regarding euphausiids in Costa Rican waters. We analyzed euphausiid specimens collected around Isla del Coco National Park during 2011 and 2012. A total of 130 specimens were analyzed and 13 euphausiid species were identified, belonging to four genera and one family. An annotated list of species is presented, with photographs and details for their identification. All species found represent new records for waters around Isla del Coco in the Costa Rican Pacific. The most frequent species were Euphausia diomedeae, Euphausia distinguenda, Nematoscelis gracilis and Stylocheiron affine. Rev. Biol. Trop. 64 (Suppl. 1): S221-S230. Epub 2016 February 01.

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Euphausiids (also known as krill) are a group of shrimp-like holoplanktonic crustaceans that inhabit all oceans (Baker, Boden, & Brinton, 1990; Everson, 2000). They are an important part of the energy transfer between trophic webs of marine ecosystems, being effective phytoplankton grazers and preyed upon by diverse organisms including large invertebrates, fishes, sea birds, seals and whales (Mauchline, & Fisher, 1969; Takashi, 1983; Williams, 1985; Agersted, Nielsen, Munk, Vismann, & Arendt, 2011). Their carcasses and fecal pellets transport organic matter to deep waters and sediments (Wheeler, 1967; Fowler, & Small, 1972). Euphausiids may also affect the fisheries of other organisms, for example Pauly, Christensen, Dalsgaard, Froeze & Torres (1998) mentioned that overfishing of the Norway pout (Trisopetrus esmarkii), a krill predator, could lead to an increase of euphausiid abundance, which in turn prey on copepods, an important food source for other commercial fishes, such as cod and saithe. Recently, large-scale commercial krill fisheries have been developed in South Atlantic along the Antarctic Peninsula, off the Japanese coast, and off the coast of British Columbia (Nicol, & Endo, 1997). Euphausiids have specific distributional patterns associated with distinct water masses, and thus are used as indicators of oceanographic environments (Brinton, 1981; 1996; Lavaniegos, Lara-Lara, & Brinton, 1989; Lavaniegos, 1994).

The biogeography of euphausiids in the Pacific Ocean has been extensively described by Brinton (1962), and several aspects of
their biology have been also studied in this region (Brinton, & Townsend, 1980; 2003; Mauchline, & Fisher, 1969; Mauchline, 1980; Everson, 2000; Letessier, Cox, & Brierley, 2011). The Eastern Tropical Pacific (ETP) had been determined as a distinct biogeographic province (Spalding, Agostini, Rice, & Grant, 2012). Fernández-Álamo & Färber-Lorda (2006) reported euphausiids as a very well-studied taxon in this region. The first records of euphausiids in the ETP were made by Ortmann (1894) and Hansen (1912). Later, Brinton (1962; 1979) described in detail the distributional patterns of euphausiid species and their relation to oceanographic parameters. Recent studies have been conducted in the Mexican Central Pacific, which include descriptions of euphausiid distribution, abundance, biomass, biochemical composition, and effects of wind forcing, upwelling and downwelling systems, and climate-oceanographic phenomena such as El Niño on krill populations (López-Cortés, 1990; Färber-Lorda, Lavin, Zapatero, & Robles, 1994; Färber-Lorda, Lavin, & Guerrero-Ruiz, 2004; Färber-Lorda, Trasviña, & Cortés-Verdín, 2010; Ambriz-Arreola, Gómez-Gutiérrez, Franco-Gordo, Lavanieves, & Godínez-Domínguez, 2012; Gómez-Gutiérrez et al., 2014). The distribution of euphausiids had been also studied in the Colombian Pacific (López-Peralta, & Medellín-Mora, 2010). In the Central American Pacific, there have been studies on crustacean larvae (including krill) (Sánchez-Maravilla, 1986), and diel vertical migrations of euphausiids (Sameoto, Guglielmo, & Lewis, 1987).

Despite the extensive research on euphausiids from the ETP, there is less specific information regarding euphausiids in the Costa Rican Pacific and Isla del Coco (Castellanos, Suárez-Morales, & Morales-Ramírez, 2009). It is important to fill the gaps on taxonomic and diversity knowledge in marine ecosystems to identify and understand the economic and ecological relevance that these organisms might have on several oceanic areas (Costello et al., 2010). Regional checklists of marine species are also important tools for recognizing and delimiting areas in need for protection (Hendrickx, & Harvey, 1999). The present study is the first attempt to record the euphausiidae species around Isla del Coco.

MATERIALS AND METHODS

Isla del Coco (also known as Cocos Island) is located in the ETP, and represents the core of the Isla del Coco Marine Conservation Area (Fig. 1), declared UNESCO World Heritage in 1997 and RAMSAR site in 1998 (Cortés, 2008). The island is located ~500km southwest of Cabo Blanco, Costa Rica, and it is the only exposed point of the Coco Cordillera (Castillo et al., 1988; Rojas, & Alvarado, 2012). The waters around Isla del Coco are influenced by the seasonal movement of Inter-Tropical Convergence Zone (Broenkow, 1965; Alfar, 2008), periodic El Niño events (Fiedler, & Talley, 2006), and even the seasonal upwelling in the Gulf of Papagayo (Lizano, 2008). Physico-chemical analyses from waters around Isla del Coco revealed influence from both coastal and oceanic waters (Acuña, García, Gómez, Vargas, & Cortés, 2008).

In order to describe the zooplankton community from Isla del Coco, two oceanographic expeditions were carried out in March 2011 and June 2012 aboard the MV Argo and MV Undersea Hunter, respectively. For a more detailed explanation of the two oceanographic expeditions see Brenes et al. (2011) and Cortés et al. (2012). A total of 35 stations in March 2011 and 25 in June 2012 were sampled around Isla del Coco. In this paper we present results from eight of them (one from 2011 and seven from 2012) (Fig. 1).

During both oceanographic expeditions, zooplankton samples were collected using a standard General Oceanics net (202 μm mesh, 50 cm diameter, 1.5 m length) towed vertically from 100 m and 200 m deep to the surface in 2011 and 2012, respectively (Table 1). All the zooplankton samples were preserved in seawater with 4 % formalin and transported to the Zooplankton Laboratory at CIMAR, UCR. Only adult euphausiids specimens were
separated from the samples, counted and identified following Baker et al. (1990) and Brin- ton, Ohman, Townsend, Knight & Bridgeman (2000). All the specimens were deposited in the crustacean collection at the Zoology Museum, University of Costa Rica (Museo de Zoología, Universidad de Costa Rica, MZUCR).

RESULTS

A total of 130 specimens were analyzed. The present study reports 13 krill species, distributed in four genera, all belonging to the family Euphausiidae (Table 2; Figs. 2, 3, 4). All the species are new records for Isla del Coco in the Costa Rican Pacific. The most frequent species were *Euphausia distinguenda*, *Euphausia diomedeae*, *Nematoscelis gracilis* and *Stylocheiron affine*, with more than 10 specimens.

DISCUSSION

The 13 euphausiid species found in Isla del Coco were previously recorded in the ETP

Fig. 1. Surveyed area and location of sampling stations of the present work in adjacent waters to Cocos Island, Costa Rica. BIOSTAT and DOME stations from Sameoto et al., 1987.

Fig. 1. Área de estudio y localización de las estaciones de muestreo en aguas adyacentes a la Isla del Coco, Costa Rica. Estaciones BIOSTAT y DOME de Sameoto et al., 1987.

TABLE 1

<table>
<thead>
<tr>
<th>Station</th>
<th>Date</th>
<th>Time of collection</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>29/03/2011</td>
<td>18:44-20:07</td>
<td>3.0995</td>
<td>-88.31035</td>
<td>0-100</td>
</tr>
<tr>
<td>6</td>
<td>08/06/2012</td>
<td>20:46-21:40</td>
<td>5.19252</td>
<td>-87.72465</td>
<td>0-200</td>
</tr>
<tr>
<td>7</td>
<td>09/06/2012</td>
<td>00:33-01:32</td>
<td>4.8591</td>
<td>-87.72538</td>
<td>0-200</td>
</tr>
<tr>
<td>12</td>
<td>09/06/2012</td>
<td>23:35-00:35</td>
<td>4.52662</td>
<td>-86.3895</td>
<td>0-200</td>
</tr>
<tr>
<td>16</td>
<td>10/06/2012</td>
<td>19:27-20:27</td>
<td>5.19191</td>
<td>-86.38947</td>
<td>0-200</td>
</tr>
<tr>
<td>20</td>
<td>11/06/2012</td>
<td>19:10-20:20</td>
<td>5.85736</td>
<td>-87.05848</td>
<td>0-200</td>
</tr>
<tr>
<td>25</td>
<td>12/06/2012</td>
<td>18:51-19:50</td>
<td>6.8774</td>
<td>-87.0587</td>
<td>0-200</td>
</tr>
</tbody>
</table>
and waters near Costa Rica by the “Shellback” expedition in 1952 (Brinton, 1962). Sameoto et al. (1987) reported 17 euphausiid species near the Costa Rica Dome outside the Economic Exclusive Zone of Costa Rica (Fig. 1). The higher species richness reported for the Costa Rica dome is probably related with the depth range sampling (0-1000 m depth) and technique (multiple opening and closing net) (Sameoto et al., 1987), while this study only analyzed samples from 200 m and 100 m depth using a standard net. Only 65 % of euphausiid species found in Costa Rica Dome are reported for Isla del Coco. Moreover, Euphausia tenera and Nematoscelis tenella were not reported by Sameoto et al. (1987) from the Dome station; however, both species were collected in the BIOSTAT station (off Central American coast). The euphausiid species assemblage of Isla del Coco should be determined by the particular oceanographic dynamics surrounding the island (Broenkow, 1965; Fiedler, & Talley, 2006; Acuña et al., 2008; Alfaro, 2008; Lizano, 2008).

Brinton (1979) grouped the euphausiids from ETP by biogeographic and hydrographic affinities. The non-migrating warm cosmopolites are N. tenella, S. affine, Stylocheiron carinatum, Stylocheiron longicorne and Stylocheiron maximum. The species that proliferate in the north and south margins of ETP are Euphausia eximia, Nematobrachion flexipes and Euphausia gibboides. These species are found in the low oxygen layer, but are more abundant in its margins. The equatorial endemic species are adapted to migrate into the low oxygen layer. This group includes E. diomedeae, E. distinguenda, Euphausia lamelligera and N. gracilis. Finally, E. tenera is a widely distributed species, thus it was not included in any group by Brinton (1979). We emphasize that the most common species in the present study were mainly from the equatorial endemics group (E. distinguenda, E. diomedeae and N. gracilis), and S. affine, a non-migrating warm cosmopolite species that can also be found through the low oxygen layer.

Isla del Coco hosts a high marine biodiversity (Cortés, 2012), which might also apply for

### TABLE 2
List of euphausiid species, number of specimens and sites of collection in waters around Isla del Coco, Costa Rica

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of specimens</th>
<th>Stations</th>
<th>Catalog number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euphausia diomedeae</td>
<td>18</td>
<td>6, 7, 12, 16, 23</td>
<td>3319-06, 3339-07, 3356-02, 3358-01, 3359-02</td>
</tr>
<tr>
<td>E. distinguenda</td>
<td>43</td>
<td>6, 7, 12, 16, 20, 21, 25</td>
<td>3319-07, 3320-02, 3339-04, 3355-05, 3356-05, 3357-04, 3358-06</td>
</tr>
<tr>
<td>E. eximia</td>
<td>5</td>
<td>20, 25</td>
<td>3355-03, 3357-01</td>
</tr>
<tr>
<td>E. gibboides</td>
<td>3</td>
<td>6, 23</td>
<td>3319-023359-01</td>
</tr>
<tr>
<td>E. lamelligera</td>
<td>2</td>
<td>25</td>
<td>3355-04</td>
</tr>
<tr>
<td>E. tenera</td>
<td>4</td>
<td>6, 7, 16</td>
<td>3319-08, 3356-04, 3358-03</td>
</tr>
<tr>
<td>Nematobrachion flexipes</td>
<td>6</td>
<td>6, 16, 21</td>
<td>3319-01, 3320-01, 3358-02</td>
</tr>
<tr>
<td>Nematoscelis gracilis</td>
<td>23</td>
<td>6, 7, 12, 16, 20, 25</td>
<td>3319-05, 3339-05, 3355-02, 3356-01, 3357-02, 3358-04</td>
</tr>
<tr>
<td>N. tenella G.O. Sars, 1883</td>
<td>1</td>
<td>12</td>
<td>3339-06</td>
</tr>
<tr>
<td>Stylocheiron affine</td>
<td>13</td>
<td>6, 7, 12, 16, 20, 21, 25</td>
<td>3319-03, 3320-03, 3339-01, 3355-01, 3356-03, 3357-05, 3358-05</td>
</tr>
<tr>
<td>S. carinatum G.O. Sars, 1883</td>
<td>8</td>
<td>6, 12, 21</td>
<td>3319-04, 3339-02</td>
</tr>
<tr>
<td>S. longicorne G.O. Sars, 1883</td>
<td>3</td>
<td>20</td>
<td>3357-03</td>
</tr>
<tr>
<td>S. maximum Hansen, 1908</td>
<td>1</td>
<td>12</td>
<td>3339-03</td>
</tr>
</tbody>
</table>
Fig. 2. (A) *Euphausia diomedeae*, bifid lappet in first antennular segment; (B) *Euphausia distinguenda*, conspicuous keel in the third antennular segment with a little denticule; (C) *Euphausia eximia*, pectinate lappet in the first antennular segment; (D) *Euphausia gibboides*, conspicuous keel in the third antennular segment pointed forward; (E) *Euphausia lamelligera*, movable plate in the second antennular segment; (F) *Euphausia tenera*, third antennular segment without a keel, eyes are little and oval. Scale in A, B, C, D, E, and F=500 μm.

Fig. 2. (A) *Euphausia diomedeae*, proceso antenular bifido en el primer segmento antenular; (B) *Euphausia distinguenda*, quilla conspicua en el tercer segmento antenular; (C) *Euphausia eximia*, proceso antenular pectinado en el primer segmento antenular; (D) *Euphausia gibboides*, quilla conspicua en el tercer segmento antenular apuntando hacia adelante; (E) *Euphausia lamelligera*, placa móvil en el segundo segmento antenular; (F) *Euphausia tenera*, el tercer segmento antenular sin quilla, ojos pequeños y ovales. Escala en A, B, C, D, E y F=500 μm.
Fig. 3. (A) *Nematobrachion flexipes*, rounded lappet in the first antennular segment; (B) *N. flexipes*, mid-dorsal spines in the abdominal segments 3-6; (C) *Nematoscelis gracilis*, size of upper lobe of the eye very similar to lower lobe; (D) *N. gracilis*, dactylus and propodus of the first thoracic leg; (E) *Nematoscelis tenella*, upper lobe of the eye bigger than the lower lobe. Scale in A, C, D, E and F=500 μm. Scale in B=1 mm.

Fig. 3. (A) *Nematobrachion flexipes*, proceso antenular redondeado en el primer segmento antenular; (B) *N. flexipes*, espinas medio-dorsales en los segmentos abdominales 3-6; (C) *Nematoscelis gracilis*, tamaño del lóbulo superior del ojo similar al lóbulo inferior; (D) *N. gracilis*, dáctilo y propodo de la primera pata torácica; (E) *Nematoscelis tenella*, lóbulo superior del ojo mucho más grande que el lóbulo inferior. Escala en A, C, D, E y F=500 μm. Escala en B=1 mm.
Fig. 4. (A) *Stylocheiron affine*, upper ocular lobe with 4-8 enlarged crystallines in transversal row; (B) *Stylocheiron carinatum*, upper ocular lobe short and narrow, with parallel anterior and posterior margins that sharply join in the lower lobe; (C) *S. carinatum*, the posterior margin of the propodus in the third thoracic leg bears a tubercle with a setae; (D) *Stylocheiron longicorne*, upper ocular lobe with 19 enlarged crystallines in transversal row; (E) *S. longicorne*, abdominal segments; (F) *Stylocheiron maximum*, eyes whit a sharp constriction between the upper and lower lobes, the upper lobe is smaller than the lower. Scale in A, B, C and D=500 μm. Scale in E and F=1 mm.

Fig. 4. (A) *Stylocheiron affine*, lóbulo superior con 4-8 cristalinos alargados en línea transversal; (B) *Stylocheiron carinatum*, lóbulo ocular superior corto y delgado, con los márgenes que se unen abruptamente al lóbulo inferior; (C) *S. carinatum*, el margen posterior del propodo de la tercer pata torácica porta un tubérculo con una seta; (D) *Stylocheiron longicorne*, lóbulo ocular superior con 19 cristalinos alargados en línea transversal; (E) *S. longicorne*, segmentos abdominales; (F) *Stylocheiron maximum*, ojos con una constricción marcada en medio de los lóbulo superior e inferior, el lóbulo superior es más pequeño que el inferior. Escala en A, B, C y D=500 μm. Escala en E y F=1 mm.
euphausiids. The waters around the island host 22% of the 59 species reported for the Pacific Ocean (Brinton, 1962; 1979) and 55% (20 species) for Central American Pacific waters (Castellanos et al., 2009). Compared with studies from the Central Pacific coast of Mexico (Färber-Lorda et al., 1994; 2010; Ambriz-Arreola et al., 2012) that have reported ten or less species, this study reports 13 species with less sampling effort. Here we present useful pictures that may help in identification of specimens from Costa Rican Pacific. The specimens analyzed in the present study were the first euphausiids deposited at the crustacean collection of the Museum of Zoology, University of Costa Rica.

Although this is the first effort to record the euphausiid diversity from Isla del Coco, samples from deeper waters are needed to found deep-water distributed species reported for Central American waters (Brinton, 1962; 1979; Sameoto et al., 1987; Castellanos et al., 2009). Moreover, information regarding the vertical distribution, ecological relationships, and temporal patterns of species composition is still needed to understand the dynamics of krill, which might be an important component for ecosystems and fisheries in Costa Rican waters. Therefore, our future goal is to assess the euphausiid community diversity and ecology in the Costa Rican Pacific waters, and we are currently preparing an ecologically focused work.

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