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New records of parasitic copepods (Copepoda: Pandaridae, Eudactylinidae, Caligidae) on elasmobranchs (Chondrichthyes) in the Gulf of Mexico

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The aim of this study was to identify the parasitic copepod species in some elasmobranchs (two rays and four shark species) that are commercially important in the Southern Gulf of Mexico (Mexico). In the spotted eagle ray, *Aetobatus narinari* six species of parasitic copepods (*Alebion* sp., *Caligus dasyaticus*, *C. haemulonis*, *Euryphorus suarezi*, *Lepeophtheirus acutus* and *L. marginatus*) were found and in the Southern stingray *Hypanusamericanus* two species (*C. dasyaticus* and *Euryphorus* sp.). The four shark species (*Carcharhinus leucas*, *C. limbatus*, *C. plumbeus* and *Sphyrna tiburo*) that were examined had at least one copepod species. The copepod species found on *C. leucas* were: *Nesippus orientalis*, *Nemesis* sp. and *Paralebion elongatus*; in *C. limbatus*: *Tuxophorus caligodes*, *L. longispinosus* and *Pandarus sinuatus*; in *C. plumbeus*: *Pandarus* sp. and in *S. tiburo*: *Eudactylina longispina*. The copepod species recorded in this study belong to families Caligidae, Pandaridae and Eudactylinidae, which had not been documented in the Mexican coast off the Gulf of Mexico, contributes to the knowledge of the biodiversity of parasitic copepods in Mexico.
Key words: Copepods, crustaceans, ectoparasites, elasmobranchs, fish parasites, Gulf of Mexico.

Nuevos registros de copépodos parásitos (Copepoda: Pandaridae, Eudactylinidae, Caligidae) en elasmobranquios (Chondrichthyes) en el Golfo de México

El objetivo de este estudio fue identificar las especies de copépodos parásitos en algunos elasmobranquios (rayas y tiburones) de importancia comercial en el sudeste del Golfo de México (México). En la raya pinta, *Aetobatus narinari* se encontraron seis especies de copépodos parásitos (*Alebion* sp., *Caligus dasyaticus*, *C. haemulonis*, *Euryphorus suarezi*, *Lepeophtheirus acutus* y *L. marginatus*) y en la raya látigo americana *Hypanus americanus*, dos especies (*C. dasyaticus* y *Euryphorus* sp.). Las cuatro especies de tiburones examinadas (*Carcharhinus leucas*, *C. limbatus*, *C. plumbeus* y *Sphyrna tiburo*) tuvieron al menos una especie de copépodo. Las especies de copépodos encontradas en *C. leucas* fueron: *Nesippus orientalis*, *Nemesis* sp. y *Paralebion elongatus*; en *C. limbatus*: *Tuxophorus caligodes*, *L. longispinosus* y *Pandarus sinuatus*; en *C. plumbeus*: *Pandarus* sp. y en *S. tiburo*: *Eudactylina longispina*. Las especies de copépodos registradas en el presente estudio pertenecen a las familias Caligidae, Pandaridae y Eudactylinidae, que no habían sido documentadas para las costas mexicanas del Golfo de México, con lo cual se contribuye al conocimiento de la biodiversidad de los copépodos parásitos en México.
Palabras clave: Copépodos, crustáceos, ectoparásitos, elasmobranquios, parásitos de peces, Golfo de México.

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Introduction

Elasmobranchs share part of their geographical distribution in all tropical and subtropical oceans. Both rays and sharks species are located on the top of the food chain and also show a broad food pattern that includes both planktonic and benthic organisms from coastal areas, estuaries, shallow freshwater creeks and coastal lagoon systems (Compagno 1999, Randhawa & Poulin 2010). These food habits provide and exceptional habitat for a variety of parasitic fauna

(Caira 1990, Caira *et al.* 2005, Randhawa and Poulin 2010, Palm 2011) and give them a great potential as definitive hosts in the parasitic system based on trophic transmission and biological indicators (Vankara *et al.* 2007, Haseli *et al.* 2010, Palm 2011).

The spotted eagle ray *Aetobatus narinari* (Euphrasen 1790), for example, is currently considered as a threatened species by the Red List of the International Union for Conservation of Nature red list (IUCN), because of their low reproductive potential and intense and unregulated fishing, which probably have caused the decline of their populations (Compagno 1999, Kyne & White 2006). Particularly, in the Southern Gulf of Mexico, the spotted eagle ray remains as a target species for fisheries. In fact, it is the second most captured batoid in the region (about 40 tons/year) (CONAPESCA 2013[1]). A similar situation occurs with small shark species in this region, which are usually sold fresh and whole, and in local markets can be also found as dried and salted fillets (Bonfil 1997).

However, despite the economic and ecologic importance of these organisms, parasitological studies on elasmobranchs are in general scarce for this region, particularly those related with parasitic copepods that may affect them. The impact of "sea lice" a common name used for ectoparasitic copepods is well known to cause serious cutaneous lesions and mortality in farmed teleosts (Costello 2009), as they graze the epidermis, often inducing secondary infections (Benz 1981), and causing destruction of gill tissue, emaciation and sometimes death (Dezfuli *et al.* 2011).

The life cycle of these small aquatic crustacean parasites is described in De Meeûs *et al*. (1990). Generally, they have a direct cycle with a fairly long free-swimming phase (at least three days). Once attached to the host, the parasite becomes mucophagous. Mating occurs on the body surface of the host and, once fertilized, females colonise the gill cavity where they lay eggs that develop and give birth to free swimming larvae. Most parasitic copepods parasitize more than one host (Álvarez & Winfield 2001), showing in general very little specificity. Regarding their distribution, it seems to be worldwide as they, like their hosts, occur in all warm and temperate seas.

The aim of the present study was to identify the parasitic copepods in six elasmobranch species (two ray species and four sharks) of commercial importance in the coastal zone of Tabasco and Campeche, Mexico. The present study contributes to the knowledge of biodiversity of parasitic copepods from marine fish in Mexico.

Materials and methods

During the years 2013-2014, two species of rays *Hypanus americanus* (Hildebrand & Schroeder 1928), n = 27, and *A. narinari*, n = 5, and four of sharks *C. leucas* (Valenciennes 1839), n = 6; *C. limbatus* (Valenciennes 1839), n = 9; *C. plumbeus* (Nardo 1827), n = 4, and *S. tiburo* (Linnaeus 1758), n = 24, were measured (total length and width in rays and length in sharks) and inspected for parasitic copepods. These elasmobranch species were obtained from commercial catches in four localities from Tabasco and Campeche (Mexico): San Pedro (18°64'09" N, 92°46'88" W), Champoton (19°21' N, 90°43' W), Ciudad del Carmen (18°39'38" N, 91°48'51" W), and Seybaplaya (17°51' N, 89°06' W) (Fig. 1). All elasmobranchs were washed with freshwater and visually examined for the presence of parasitic copepods on skin, fins and gills. The washing material and gills were transported in individual plastic bags in a cool box to the Parasitology Laboratory at the Universidad Autónoma del Carmen (UNACAR) for parasitological examination. The examination of copepods on the body surface of the hosts was performed under good illumination, and gill arches were removed from each fish and carefully inspected in a Petri dish using a LEICA MZ 9.5 stereomicroscope. The plastic bag contents were also examined for the presence of detached copepods. Parasites found on each fish were preserved in labeled vials with 70% ethanol. The identification of the parasitic copepodswas performed following Yamaguti (1963),

1. CONAPESCA 2013. Base de datos de producción. Anuario 2013. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación [*in Spanish*]. http://www.conapesca.gob.mx/work/sites/cona/dgppe/anuarios/BASE_DE_DATOS_DE_PRODUCCION_ANUARIO_2013.zip

Kabata (1979, 1988, 1992a, b), Cressey & Cressey (1980, 1985), Boxshall & Halsey (2004) and Hayes *et al.* (2012). Prevalence (percent of infected hosts among all hosts examined) was determined according to Margolis *et al.* (1982).

Results

Seventy percent of the examined elasmobranch specimens harbored at least one parasitic copepod species. A total of six caligid species (family Caligidae) were found on the skin of five specimens of *A. narinari*: *Alebion* sp. Krøyer 1863, *Caligus dasyaticus* Rangnekar 1957, *Caligus haemulonis* Krøyer 1863, *Euryphorus suarezi* Morales-Serna, Rodríguez-Santiago & Gómez 2016, *Lepeophtheirus acutus* Heegaard 1943 and *Lepeophtheirus marginatus* Bere 1936 (Fig. 2). The most abundant copepod species were *Alebion* sp. (up to 79 individuals per host) and *E. suarezi* (37 individuals per host). In the Southern stingray *H. americanus* two species were found *C. dasyaticus* and *Euryphorus* sp. The prevalence of the seven-copepod species was 100%, as they were present in all the examined hosts.

In the case of sharks, eight copepod species were found on its skin. *Nessipus orientalis* Heller 1865 (Pandaridae), *Nemesis* sp. (Eudactylinidae) and *Paralebion elongatus* Wilson 1911 (Caligidae) were found on *C. leucas* (prevalence = 100% for the three copepod species). *Tuxophorus caligodes* Wilson 1908 (Caligidae), *Lepeophtheirus longispinosus* Wilson 1908 (Caligidae) and *Pandarus sinuatus* Say 1818 (Pandaridae) were found on *C. limbatus* (prevalence = 22.2%, 44.4% and 77.7%, respectively). *Pandarus* sp. (Pandaridae) was found on *C. plumbeus* (prevalence = 50%), and *Eudactylina longispina* (Eudactylinidae) on *S. tiburo* (prevalence = 29.1%).

Discussion

Parasitic copepods are the second and third largest group on neotropical marine and freshwater fishes, respectively (Luque & Poulin 2008). In accordance with Boxshall (2013), most of the

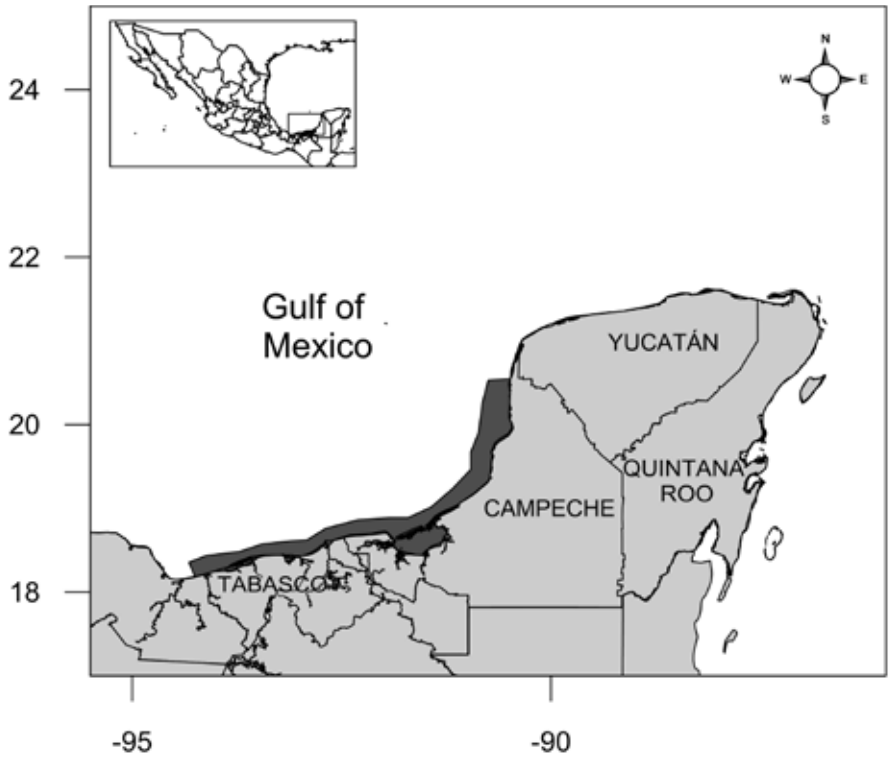

Fig. 1. Location of the study area where specimens of rays and sharks were obtained (Tabasco and Campeche, Mexico).

Fig. 2. Images of some of the parasitic copepod species reported in this study. *a*) *Paralebion elongatus b*) *Pandarus* sp. *c*) *Caligus bifurcatus d*) Side view of *Nemesis* sp. *e*) *Nessipus orientalis, f*) *Alebion* sp., *g*) *Caligus dasyaticus*, *h*) *Caligus haemulonis*, *i*) *Lepeophtheirus acutus*, and j) *Lepeophtheirus marginatus*.

copepods infecting teleost fish and elasmobranchs are mainly members of the order Siphonostomatoida, which consist of 39 families. In fact, it has been suggested that about 210 chondrichthyan species may be infected by this order of copepods (Compagno 1999). In this study, the 15 parasitic copepod species found on the six elasmobranch species are also of the order Siphonostomatoida (67% belonging to family Caligidae, 20% to Pandaridae and 13% to Eudactylinidae). This overall species diversity of parasitic copepods was within the range of that reported in elasmobranchs from other regions worldwide. For example, Luque & Tavares (2007) documented 14 parasitic copepod species on 10 species of chondrichthians collected from Brazilian waters. Their study is the highest number of parasitic copepods recorded in the Neotropics for the elasmobranch group of the family Carcharhinidae. Among the copepod species that they mentioned, *P. sinuatus* was present on *C. limbatus*, which coincided with our findings for this same shark species.

Other studies that have also recorded a great diversity of parasitic copepod species in elasmobranchs are that conducted by Henderson *et al.* (2013) and Rokicki & Bychawska (1991) in the northern Indian Ocean and the central Atlantic Ocean, respectively. In the first, the authors reported 12 parasitic copepod species (families Pandaridae and Caligidae) on 13 elasmobranch host species (Henderson *et al.* 2013). Meanwhile in the second, 14 copepod species were reported on seven elasmobranch species from the families Carcharhinidae and Sphyrnidae (Rokicki & Bychawska 1991).

Among the copepod species that were found parasitizing the elasmobranchs in this study, some have also been reported for other elasmobranch species in other regions of the world. Such is the case of *C. dasyaticus*, a common parasite species, that has been reported on stingrays of

India (Pillai 1968), Japan (Tang *et al.* 2013) and Taiwan (Ho *et al*. 2007), and C. *bifurcatus*. Also, *L. acutus* has been reported on elasmobranchs in Germany, Japan and the Netherlands, on the tiger shark *Galeocerdo cuvier* (Péron & Lesueur 1822), zebra shark, *Stegostoma fasciatum* (Hermann 1873), the Alfred manta *Mobula alfredi* (Krefft 1868), and the whale shark *Rhincodon typus* Smith 1828, held in sea pens off Okinawajima Island, Japan (Kik *et al*. 2011, Tang *et al.* 2013). In eastern India (Benz *et al.* 2007) and South Africa (Lebepe & Dippenaar 2013), *L. acutus* has even been considered a dangerous pathogen of captive elasmobranchs. This species has a broad adaptive spectrum (Kik *et al.* 2011) as they can be found in a wide regime of salinity and temperature, as well as in a vertical range from highland lakes to the ocean trenches (Huys & Boxshall 1991). In addition, it can be found in both, the water column (planktonic) and the sediment (benthic) in association with other organisms (symbionts). In this sense, Álvarez & Winfield (2001) observed that the site of attachment is variable among hosts, being the most usual sites the gills, nasal cavity, mouth, tail, fin and body surface in general. These authors also documented that most species of sharks appear to have one to a few species of copepods, and harbor one to several hundred individuals of each of those species.

Moreover, the only published reports of parasitic copepods on fish species (including both, teleosts and elasmobranchs) in the Mexican coasts of the Gulf of Mexico are those of Causey (1960), who reported 25 genera and 46 species of parasitic copepods. Álvarez & Winfield (2001) reported *Dinemoura latifolia* (Steenstrup & Lütken 1861) and *Pandarus smithii* Rathbun 1886 from sharks in Veracruz State. In our research group, Morales-Serna *et al.* (2016) described for the first time to *Euryphorus suarezi* on the spotted eagle ray *A. narinari* from Tabasco and Campeche. In fact, in the recent review by Morales-Serna *et al*. (2012) there had been only five species of parasitic copepods recorded in elasmobranchs for the Mexican coasts, all of them from sharks and rays collected from the northwestern coasts of Mexico. However, of these species of copepods that they found in elasmobranches none coincides with those reported in our study. The bull shark (*C. leucas*) is the only shark species in which parasitic copepods have been reported in both coasts of Mexico: Pacific (Cressey 1972) and Gulf of Mexico (this study). In the Mexican Pacific, only one species of parasitic copepod was reported in this shark, while in the Gulf of Mexico this study reports three. Another interesting finding was that both ray species shared two species of parasitic copepods despite having different habits (one benthonic and the other pelagic). Although the exact geographic coordinates and depths of catch locations were not available, it is known that these two ray species share its distribution range in the Gulf of Mexico, so it is possible that this kind of ectoparasites are acquired in places where they coexist.

In summary, this study provides a baseline of new information on the distribution of species of parasitic copepods from six commercially important elasmobranch species in the Southern Gulf of Mexico. A total of 15 parasitic copepod species were reported here, which are representatives of three families (Caligidae, Pandaridae and Eudactylinidae) that had not been documented for elasmobranchs in Mexican coasts of the Gulf of Mexico. Moreover, despite these species of rays and sharks are common target for local commercial fisheries, the limitation of the study is that these fish are not so abundant in the region. Consequently, their capture to perform parasitological studies is limited. The present study is part of an ongoing survey of the parasitic copepods on fishes from coastal waters in the Southern Gulf of Mexico.

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