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## Review

# Deep-water shrimp fisheries in Latin America: a review

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**ABSTRACT.** Commercial fisheries are expanding their activities into deeper water. The life history features of these deep-water resources make them more vulnerable to exploitation than most shallow-water resources. Moreover, the apparent lack of solid information about the ecology of most deep-water species represents a major limitation for the development and implementation of management strategies. This scenario has caused great concern regarding the sustainability of these resources and the possible environmental impacts on the deep-sea ecosystem. In Latin America, commercial fisheries are going deep as well, and considering the above-mentioned concerns, we felt the need to compile the available information about the deep-water shrimp resources and the current status of their fisheries in Latin America. Focusing on Mexico, Central America, Peru, Chile and Brazil, this review describes the exploited species, and, whenever available, the fishing fleet, fishery statistics, and management strategies. A total of 17 species (10 spp. of Penaeoidea; 7 spp. of Caridea) are of commercial interest in Latin America, but deep-water shrimps are currently fished only in Costa Rica, Colombia and Chile. An implemented management plan exists in Chile and Colombia, while Brazil approved fishery regulations for the aristeid fishery, which were never implemented. Considering the lack of information about the biology of the deep-water shrimps, which hinders the development of adequate management strategies, we see the urgent need to improve the communication and collaboration between the different stakeholders in Latin American. We suggest the establishment of a searchable and constantly updated database, which may serve as a valuable source of information for researcher and decision makers. Finally, we propose the development of regional research plans aimed towards supporting measurements for a sustainable use of deep-water shrimps in Latin America.

**Keywords:** sustainability, management, fishery statistics, Penaeoidea, Caridea, Brazil, Mexico, Central America, Colombia, Peru, Chile.

## Pesquerías de camarones de aguas profundas en América Latina: una revisión

**RESUMEN.** La pesca comercial está expandiendo sus actividades hacia aguas profundas. Las características del ciclo de vida de estos recursos de aguas profundas los hacen más vulnerables a la explotación que la mayoría de los recursos de aguas someras. Además, la falta de información sobre la ecología de la mayoría de las especies de aguas profundas constituye una limitación importante para el desarrollo e implementación de estrategias de manejo. Este escenario ha causado preocupación sobre la sustentabilidad de estos recursos y de los posibles impactos ambientales en los ecosistemas de aguas profundas. La pesca comercial en América Latina se extiende también hacia aguas profundas y, considerando las preocupaciones anteriormente mencionadas, se requiere la necesidad de compilar la información disponible sobre los recursos de camarones de aguas profundas y la situación actual de estas pesquerías en América Latina. Esta revisión se enfoca en México, Centro América, Perú, Chile y Brasil y describe las especies explotadas, la flota pesquera (siempre cuando sea disponible), las estadísticas pesqueras y las estrategias de manejo. Un total de 17 especies (10 spp. de Penaeoidea y 7 spp. de Caridea) son de interés comercial en América Latina; sin embargo, camarones de

aguas profundas solo se pescan actualmente en Costa Rica, Colombia y Chile. Un plan de manejo implementado existe en Chile y Colombia, mientras que en Brasil se aprobaron regulaciones sobre la pesca de camarones de la familia Aristeidae, pero éstas nunca han sido implementadas. Considerando la falta de información sobre la biología de los camarones de aguas profundas, lo que dificulta el desarrollo de estrategias adecuadas de manejo, se requiere urgentemente mejorar la comunicación y colaboración entre los diferentes actores en Latinoamérica. Se sugiere establecer un banco de datos abierto para búsquedas y actualizarlo constantemente, lo que servirá como fuente valiosa de información para investigadores y quienes deben tomar decisiones. Finalmente, se propone desarrollar un plan de investigación para apoyar medidas hacia el uso sustentable de camarones de aguas profundas en América Latina.

**Palabras clave:** México, América Central, Colombia, Perú, Chile, Brasil, sustentabilidad, manejo, estadísticas de pesca, Penaeoidea, Caridea.

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## INTRODUCTION

Many marine fisheries, especially those in coastal waters, are fully exploited, threatened by overexploitation or already collapsed. According to Pauly (2009), demersal resources of all large shelves of the world have been depleted by the end of the 20th century. Declining catches in coastal zones and the concomitant increase in demand for seafood have forced the fishing industry to expand their activities into offshore and deep-water areas (Morato *et al.*, 2006). As a consequence, the mean depth of bottom marine fish catches has increased from around 103 m in the early 1950s to 145 m in 2001, which represents a 42 m increase (Morato *et al.*, 2006). Associated with this bathymetric shift in bottom fishery activities is an increase in the mean longevity of the catch, most dramatically since the early 1990s (Morato *et al.*, 2006).

This trend is a serious concern, because deep-water species exhibit a series of life history traits, which make them especially vulnerable to overexploitation and extinction with a low capacity to recover from over-exploitation (*e.g.* Jennings *et al.*, 1998; Cheung *et al.*, 2005, Morato *et al.*, 2006). Moreover, the apparent lack of solid information about the ecology of most deep-water species represents a major limitation for the development and implementation of management strategies for deep-water resources (Polidoro *et al.*, 2008). Bensch *et al.* (2008) and Ramirez-Llodra *et al.* (2011) provided an overview of the current status of high seas bottom fisheries around the world, focusing principally on deep-water fisheries. The authors concluded that even basic information concerning total catch, by-catch species and life history of the deep-water target species is deficient and therefore not enough to generate conservation and management strategies. According to

these authors, it is critical to assess these aspects if fisheries management intends to effectively ensure the long-term sustainability of these resources.

Deep-water shrimp fisheries have been developed in different parts of the world. In the northwest Atlantic, Canadian vessels began the exploitation of the northern shrimp *Pandalus borealis* between the late 1970s to early 1980s. Recently, many other countries reported catches of this species from high seas (Bensch *et al.*, 2008). Different *Heterocarpus* species have been considered as large, relatively unexploited resources that may prove valuable to Pacific island nations and states; *H. laevigatus* and *H. ensifer* were identified as having the greatest commercial potencial. Ostazeski (1997) provided an overview of the deep-water shrimp fishery targeting *H. laevigatus* in northern Mariana Islands. He concluded that this fishery has yet to be fully exploited, but high costs involved in fishing in these deep-water areas may be more limiting than the sustainable yield. Well-established deep-water shrimp fisheries (*Aristaeomorpha foliacea* and, in particular, *Aristeus antennatus*; for review of the biology see Sardà *et al.*, 2003; Politou *et al.*, 2005) have been developed in the Mediterranean. Commercial fishing for these red shrimps started in the Ligurian Sea in the 1930s (Sardà *et al.*, 2004). Stocks of the two aristeid shrimps collapsed in the 1970s, and fishing resumed following signs of stock recovery in 1985 (Sardà *et al.*, 2004). A revision of the current status of the aristeid fishery in the Mediterranean is provided by Bensch *et al.* (2008).

Latin American fisheries are tending towards deeper water as well (Arana *et al.*, 2009a). Several publications provide clear evidence for the increasing scientific and commercial interest in deep-water resources (*e.g.* Arana *et al.*, 2002; Wehrmann &

Echeverría-Sáenz, 2007; Wehrmann & Nielsen-Muñoz, 2009). More recently, Arana *et al.* (2009b) edited a compilation of information about deep-water fisheries and resources from both the Pacific and Atlantic coasts of Latin America. While commercial deep-water fisheries generally target bony and cartilaginous fishes (FAO, 2007), the situation in Latin America seems to be different: in this geographical zone, deep-water fishing activities focus largely on benthic and demersal invertebrates, and despite their relatively recent fishing history, 45% of these resources are already considered to be exploited or overexploited (Arana *et al.*, 2009a).

Considering the above-mentioned situation, we felt the need to prepare an overview of the current status of the deep-water shrimp fisheries in Latin America. The present review compiles available information about these deep-water resources principally in Mexico, Central America, Peru, Chile and Brazil. In some of these countries/regions, no commercial fisheries have been established yet; in such cases, we gathered the available data obtained from scientific surveys carried out to assess the potential of the resources. The review provides a brief introduction to the deep-water shrimp species of commercial interest in Latin America, and presents, whenever available, information about the fishing fleet, fishery statistics, and management strategies. We finish our review with some recommendations for the future development of these fisheries and the associated research programs.

## I. MEXICO

**I.1. Introduction.** National fisheries production in Mexico has reached a plateau around an annual record of 1.5 million metric ton (CONAPESCA, 2008). There seems to be little possibilities of substantially increasing this production while considering only traditional fishery resources, which are mainly caught in shallow waters (<100 m depth) of the continental shelf. Thus, the exploration of potential deep-water fishery grounds and other new fishery resources appears to be an alternative to raise this production in the Exclusive Economic Zone (EEZ) of Mexico, which covers more than 3 million km<sup>2</sup> (Gracia, 2001). Nonetheless, only scattered information on the potential fishery resources of this enormous area is available.

Shallow water penaeid shrimps, which can be found both in coastal lagoons and in the continental shelf, constitute the most important fishing resource in Mexico. More than 15 species are reported to occur in the Gulf of Mexico (Vázquez-Bader & Gracia, 1994; Gracia & Hernández-Aguilera, 2005), but only six of

them are commercially exploited (*Farfantepenaeus aztecus*, *F. duorarum*, *F. brasiliensis*, *Litopenaeus setiferus*, *Sicyonia brevirostris* and *Xiphopenaeus kroyeri*). Shallow water penaeid shrimps have been subjected to both artisanal inshore and industrial offshore fisheries and, as in many other parts of the world, these resources are overfished. High exploitation rates caused both growth and recruitment-overfishing of some of the main shrimp species (*F. duorarum*, *F. brasiliensis*, *L. setiferus*) of the Gulf of Mexico (Gracia, 1996; Gracia & Vázquez-Bader, 1999). As a consequence of overfishing, the overall shrimp production of the Gulf of Mexico declined drastically after reaching its maximum yield during the 1970s-1980s (Gracia, 2004). Operations of the industrial offshore trawl fishery are limited to a depth of less than 100 m due to the bathymetric distribution of penaeid shrimps. Considering the intense trawling activities in the shelf bottoms of the Gulf of Mexico, it is unlikely to find unexploited shrimp fishing grounds of the traditionally exploited species. Therefore, the only possibility to increase shrimp catches is to find potential fishing grounds in deep-water areas in the Gulf of Mexico and in the EEZ of Pacific Mexico.

As a response to this situation, several initiatives were developed to obtain a better overview of the deep-water resources in Mexican waters. Regarding the Mexican Pacific, Hendrickx (2003, 2004) reported on the presence of four deep-water shrimp species (*Benthesicymus tanneri* Faxon, 1893; *Acantheephyra brevicarinata* Hanamura, 1984; *Heterocarpus affinis* Faxon, 1893; *Pandalopsis ampla* Bate, 1886) in the southeastern Gulf of California at depths between 600 and 2250 m. Hendrickx (2004) concluded that *H. affinis* could be considered as a target species. Starting in 2004, the project SAGARPA-CONACYT 040 aimed to carry out an exploratory fishery of deep-water shrimps in western Baja California (Flores *et al.*, 2004). The results (Flores *et al.*, 2004) showed the presence of *Pandalus platyceros* Brandt, 1851 between 126 and 252 m depth, and the species was considered as an important fishery resource yet not exploited in Mexico; the authors provided also a brief summary on the biology and fishery of this species.

Referring to the Atlantic coast of Mexico, Wicksten & Packard (2005) compiled records of 130 decapod species occurring on the continental slope (200-2500 m) and the abyssal plain (2500-3840 m) of the Gulf of Mexico. On the other hand, the Universidad Nacional Autónoma de México is conducting a scientific research program, which began in 1999 and was then resumed in 2007 (Proyecto PAPIIT IN223109-3, Biodiversidad y Recursos Pesqueros Potenciales del Mar Profundo del Golfo de México). This project aims to study and assess

potential fishing resources, mainly deep-water shrimps (between 300-1200 m depth) of the Gulf of Mexico. The ongoing research program has been conducted on board of the R/V JUSTO SIERRA. Five research cruises (1999, 2007, 2008, 2009, 2010) have been carried out as part of the ongoing project. Sampling stations were distributed along the entire Mexican Gulf of Mexico, from the Mexican border with the United States of America to the Mexican Caribbean Sea.

**I.2. Presentation of the species.** Six main deep-water shrimp species of the families Aristeidae, Solenoceridae and Penaeidae were found in the 300-1200 m depth range (Gracia *et al.*, 2010). Other crustaceans (geronid crabs, deep-water lobsters and other shrimp species) and fishes of potential commercial interest were found, too. The following deep-water shrimps, however, stood out due to their abundance and size.

*Aristaeomorpha foliacea* (Risso, 1827) (giant red shrimp; local names: “camarón rojo gigante”, “gamba española”, and “camarão moruno” in Brazil) (Fig. 1). This aristeid shrimp is widely distributed and has been reported in the eastern Atlantic from the Bay of Biscay to western Sahara, Azores, Madeira, Canary Islands, the Mediterranean Sea, and off the coast of South Africa. In the western Atlantic, the species is known to occur from Massachusetts to Florida, in the Gulf of Mexico, and in the Caribbean Sea to Brazil. It has been also collected in the Indo-West Pacific from East Africa to Japan, New Zealand and Fiji (Pérez-Farfante & Kensley, 1997; Tavares, 2002). The results of the scientific surveys (Gracia *et al.*, 2010) revealed the presence of *A. foliacea* in the entire Gulf of Mexico. This species sustains commercial fisheries in the Mediterranean (Figueiredo *et al.*, 2001; Ragonese *et al.*, 2001) and is currently exploited in Brazil (see below). The giant red shrimp has a bathymetric distribution from 250 to 1300 m depth, and is found to be associated with mud bottoms (Tavares, 2002).

*Aristaeopsis edwardsiana* (Johnson, 1867) (scarlet shrimp; local name: “carabinero”) (Fig. 2). The shrimp is found in the eastern Atlantic from Azores, Madeira, Canary Islands, Portugal and Morocco, western Sahara to South Africa, excluding the Mediterranean Sea (Pérez-Farfante & Kensley, 1997; Tavares, 2002). In the western Atlantic, the species can be found from south Grand Bank to Brazil including the Gulf of Mexico and Caribbean Sea (Pérez-Farfante & Kensley, 1997). It was also reported from the Indo-West Pacific, but species identity was not confirmed (Pérez-Farfante & Kensley, 1997). Latin American commercial fisheries targeting this aristeid shrimp have been developed in French Guiana and Brazil



**Figure 1.** The giant red shrimp *Aristaeomorpha foliacea* (Photo: Roberto Bavaresco).

**Figura 1.** Camarón rojo gigante *Aristaeomorpha foliacea* (Foto: Roberto Bavaresco).



**Figure 2.** The scarlet shrimp *Aristaeopsis edwardsiana* (Photo: Roberto Bavaresco).

**Figura 2.** Camarón carabinero *Aristaeopsis edwardsiana* (Foto: Roberto Bavaresco).

(Guéguen, 1998; Pezutto *et al.*, 2006). The species, usually inhabiting mud bottoms, is most frequently found between 400-900 m, although it has a large bathymetric distribution range reported from 274 to 1850 m depth (Tavares, 2002).

*Pleoticus robustus* (Smith, 1885) (royal red shrimp; local name: “camarón rojo real”) (Fig. 3). The distribution of this solenocerid shrimp is limited to the western Atlantic: from south of Martha’s Vineyard (Massachusetts, USA), throughout the Gulf of Mexico and the Caribbean Sea to French Guiana (Holthuis, 1980; Pérez-Farfante & Kensley, 1997; Tavares,



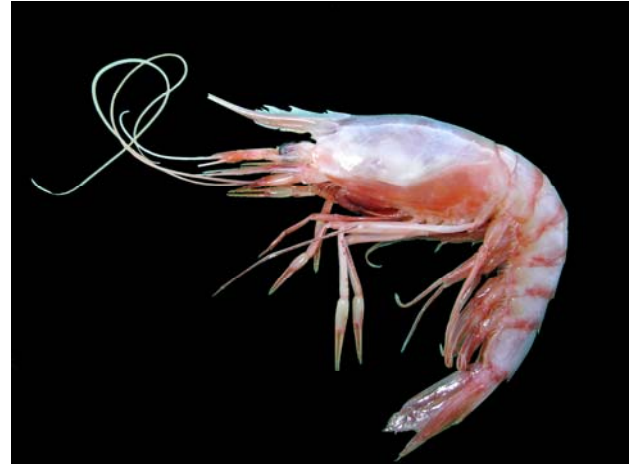
**Figure 3.** The royal red shrimp *Pleoticus robustus*.

**Figura 3.** Camarón rojo real *Pleoticus robustus*.

2002). The royal red shrimp is the basis of a small but well-established fishery in the USA waters of the Gulf of Mexico off Alabama and Florida and Florida's Atlantic coast. The fishery is most active in the north of the Gulf of Mexico averaging 123380 kg per year since 1998 (Stiles *et al.*, 2007). The species inhabits the upper continental slope between 180-730 m over blue/black mud, sand, muddy sand or white calcareous mud bottoms (Pérez-Farfante & Kensley, 1997; Tavares, 2002). During the scientific surveys in the Mexican Gulf of Mexico the species was collected between 213 and 764 m depth.

*Aristeus antillensis* A. Milne Edwards & Bouvier, 1909 (purple shrimp; local names: "alocado" or "camarón púrpura") (Fig. 4). The presence of this aristeid shrimp is restricted to the western Atlantic with a geographical distribution extending from Florida to Brazil, including the Gulf of Mexico and the Caribbean Sea (Holthuis, 1980; Pérez-Farfante & Kensley, 1997; Tavares, 2002). In Latin America, the species was seasonally exploited in French Guiana (Guéguen, 1998, 2001), and this species was also fished in Brazil, which is addressed later in this paper. Its bathymetric distribution ranges from 200 to 1144 m, although its density peaks are at 750 m depth (Pezzuto *et al.*, 2006). In the Mexican Gulf of Mexico, the shrimp was found on mud bottoms above 300 m depth.

*Penaeopsis serrata* Bate, 1881 (pink speckled shrimp; local name: "camarón rosado moteado"). The penaeoid shrimp has an ampho-Atlantic distribution and can be found on mud bottoms between 120 to 640 m (Pérez-Farfante & Kensley, 1997). This species has a potential commercial importance, but its compa-



**Figure 4.** The purple shrimp *Aristeus antillensis* (Photo: Roberto Bavaresco).

**Figura 4.** Camarón alocado *Aristeus antillensis* (Foto: Roberto Bavaresco).

atively small size may render its exploitation unappealing.

*Parapenaeus americanus* Rathbun, 1901 (rose shrimp; local name: "camarón rosa"). This species of the family Penaeidae is distributed in the western Atlantic, and has been reported from the Gulf of Mexico to Uruguay (Pérez-Farfante & Kensley, 1997). It can be found between 190-412 m, associated to mud bottoms (Pérez-Farfante & Kensley, 1997). This species is less important in terms of number and weight compared to the other deep-water shrimp species found in Mexican waters of the Gulf of Mexico.

Many of these species have a wide worldwide distribution, but all of them are found along Latin America and some of them are already commercially exploited. Currently, deep-water shrimps are not subject to a commercial fishery in Mexico. *Pleoticus robustus* is the only deep-water shrimp that is supporting fishery activities in USA waters of the Gulf of Mexico.

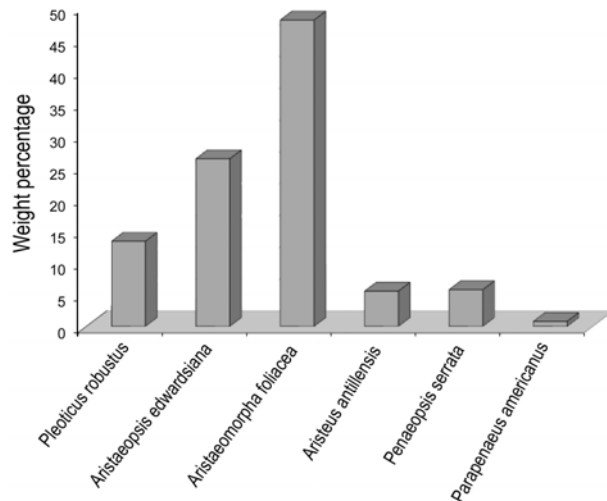
**I.3 Scientific sampling method.** Sampling of benthic communities (1999-2010) was carried out day and night using a single semi-commercial shrimp trawl net (18 m mouth aperture, 4.5 cm stretched mesh body and 1.5 cm stretched mesh cod-end) after surveying the bottom with a sub-bottom profiler echosounder. When finding appropriate bottoms for trawling, exploratory trawling was done during 30 minutes at a speed of 2.5-3 knots. Distance travelled by the net was measured using the ship's high precision GPS; the



distance covered in 30 minutes varied between 0.8 and 1.2 nautical miles, depending on sea conditions.

**I.4. Catch statistics.** In the Gulf of Mexico, the most important deep-water shrimp species (in terms of biomass) were *A. foliacea*, *A. edwardsiana* and *P. robustus*, which together represented about 90% of the total weight catch (Fig. 5). Their mean sizes were also the largest ones registered along the scientific survey, varying between 35 and almost 60 mm CL. The remaining 10% of the deep-water shrimp biomass was constituted by *A. antillensis*, *P. serrata* and *P. americanus*, which were very abundant in some samples, but mean size of these species was comparatively small. The smallest species was *P. americanus* with a mean size of 22.5 mm CL (Table 1).

Catch per unit effort (CPUE) in kilograms per hour was used as an index of deep-water shrimp abundance and was arranged by 100 m depth strata. CPUE in the scientific survey varied from values near zero (0.02 kg/h) to a maximum CPUE of 16.4 kg h<sup>-1</sup>. Catch rates showed high variability between different strata and geographical areas sampled. This agrees well with the typical patchy distribution of deep-water shrimps (Anderson & Lindner, 1971; D'Onghia *et al.*, 1998; Belcari *et al.*, 2003). Nonetheless, higher catches were consistently found in the 300-700 m depth interval (Fig. 6). The catch rates obtained in the Gulf of



**Figure 5.** Species compositions (percentages) by weight of deepwater shrimp catches based on data collected during cruises carried out between 1999 and 2010 in the Gulf of Mexico.

**Figura 5.** Composición porcentual en peso por especie de camarones de aguas profundas, obtenida de datos recolectados en cruceros realizados entre 1999 y 2010 en el golfo de México.

Mexico scientific survey are within the range of CPUE values reported for several deep-water shrimp fisheries in the world: for example, in Latin America, there are high mean annual CPUE values reported for *A. edwardsiana* fisheries in Brazil from 4.7 to 14 kg h<sup>-1</sup> (Dallagnolo *et al.*, 2009a). On the other hand, CPUE values reported for *A. foliacea* and *A. antillensis* from the Brazilian deep-water shrimp fisheries are considerably lower, varying between 0.76–6.3 kg (this paper) and 0.005–2.4 kg (Dallagnolo *et al.*, 2009a), respectively. CPUE registered in deep-water shrimp fisheries for *A. foliacea* and *A. antennatus* in the Mediterranean Sea and eastern Atlantic off Portugal have a range similar to the CPUE obtained in the Gulf of Mexico (0–12 kg h<sup>-1</sup>) (D'Onghia *et al.*, 1998; Figueiredo *et al.*, 2001; Carbonell & Azevedo, 2003; Can & Aktas, 2005). Also, Pezutto *et al.* (2006) have reported CPUE figures for *A. edwardsiana* in the southern region and the northern border of the ZEE Brazil that varied between 6.5 to 9.7 kg h<sup>-1</sup>.

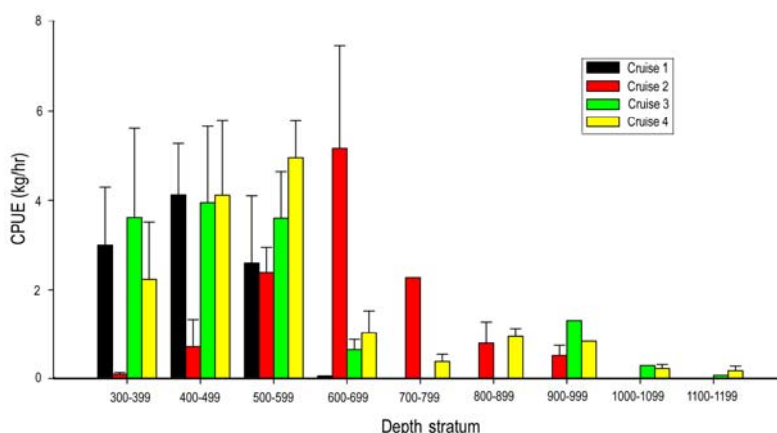
Deep-water shrimp catch rates recorded in the Gulf of Mexico seem to be lower than the mean annual CPUE of some of the deep-water fisheries conducted in the world. However, results of an exploratory scientific survey maybe not totally comparable to those of commercial fishing operations of a specialized fleet of commercial trawlers. Statistics of a developed fishery are more precise due to a larger fishing effort and an increased knowledge concerning profitable fishing grounds. Nevertheless, the CPUE recorded in the Gulf of Mexico serves as an index of the abundance of deep-water shrimp. Gracia *et al.* (2010) pointed out that about 40% of the hauls in the SW Gulf of Mexico resulted in high catch rates of above 5 kg h<sup>-1</sup>. It is also important to highlight that deep-water shrimp CPUEs compare well with, and sometimes are even higher than current CPUEs obtained in the depleted coastal white and pink shrimp fisheries (1.1–10 kg) of the Mexican Gulf of Mexico (INAPESCA, 2009). These two coastal species play an important role in sustaining local shrimp fisheries in Mexico in spite of the apparent overexploitation of these resources.

Deep-water shrimp abundance indexes recorded for the Gulf of Mexico, as well as the extent of its potential distribution area between 300 and 1000 m depth (about 60,000 km<sup>2</sup>; Fig. 7) reinforce the expectation that these species may represent a valuable fishing resource. In this large area there is a complex topography, including basins and submarine canyons, occasionally with high concentrations of deep-water shrimps (Fig. 7). It seems unlikely, however, that this potential fishery resource may reach

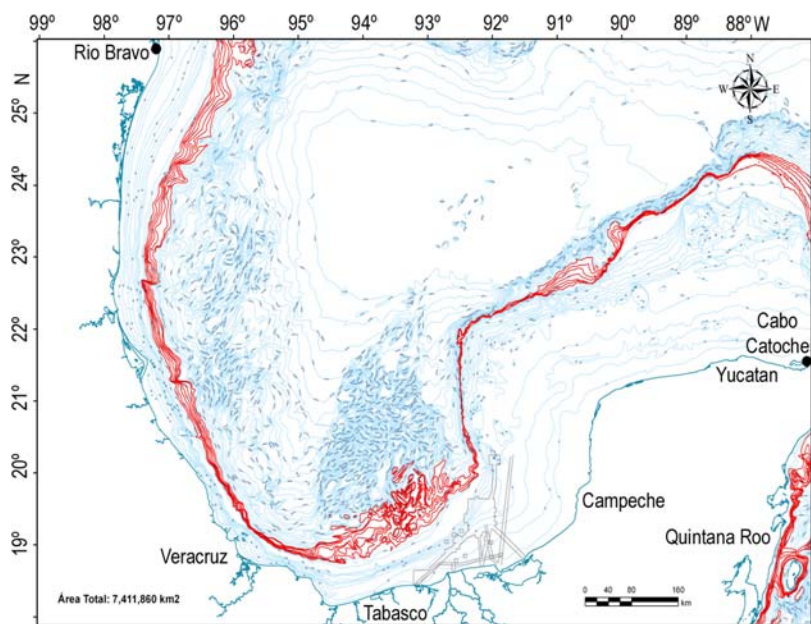
**Table 1.** Size (carapace length, SD, standard deviation) of deep-water shrimps of the Gulf of Mexico.

**Tabla 1.** Tamaño (longitud del cefalotórax, SD, desviación estándar) de camarones de aguas profundas en el golfo de México.

Species	Minimum size	Average $\pm$ SD	Maximum size	N
<i>Aristaeomorpha foliacea</i>	31.5	49.8 $\pm$ 7	84.0	4618
<i>Aristaeopsis edwardsiana</i>	28.0	58.7 $\pm$ 14	86.4	1644
<i>Pleoticus robustus</i>	25.0	43.8 $\pm$ 14	78.0	1200
<i>Aristeus antillensis</i>	17.9	34.7 $\pm$ 13	64.3	688
<i>Penaeopsis serrata</i>	17.3	23.8 $\pm$ 7	46.3	1552
<i>Parapenaeus americanus</i>	11.7	22.5 $\pm$ 4	30.4	188

**Figure 6.** Catch per Unit Effort (CPUE,  $\text{kg h}^{-1}$ ) per 100 depth strata (meters) of deepwater shrimps collected during cruises carried out between 1999 and 2010 in the Gulf of Mexico.

**Figura 6.** Captura por Unidad de Esfuerzo (CPUE,  $\text{kg h}^{-1}$ ) por estratos de 100 m, de camarones de aguas profundas en cruceros realizados entre 1999 y 2010 en el golfo de México.

**Figure 7.** Potential deepwater shrimp habitat and bottom topography of the Mexican Gulf of Mexico.

**Figura 7.** Hábitat potencial de camarones de aguas profundas y topografía del fondo marino en el sector mexicano del golfo de México.



the high yields obtained in the coastal brown shrimp (*F. aztecus*) fishery (annual production of 7,000 metric ton with a CPUE per net between 20–65 kg h<sup>-1</sup> (INAPESCA, 2010), whose stock is in good conditions and currently sustains the entire shrimp industry of the Gulf of Mexico (Gracia, 2004). However, the results obtained during the scientific research program seems to indicate that this potential fishing resource may render similar or even higher yields than those in the depleted coastal white (*L. setiferus*) and pink (*F. duorarum*) shrimp stocks; the annual production of these resources decreased to around 75 and 600 ton, respectively (Gracia, 2004; INAPESCA, 2005). It is difficult to estimate potential landing figures for these deep-water shrimps in the Gulf of Mexico with the currently available data, but it is reasonable to assume that the production will be low according to what usually occurs in established deep-water fisheries in other parts of the world (Jones *et al.*, 1994; Politou *et al.*, 2003; Pezutto *et al.*, 2006). However, even if a relatively small-scale fishery can be established, it still could represent a valuable alternative fishing resource for the troubled Mexican shrimp industry of the Gulf of Mexico.

**I.5. Conclusions.** Developing this potential deep-water shrimp fishery requires an integrative research initiative that should consider the following aspects: 1) stock assessment of deep-water shrimps; 2) delimitation of fishing grounds, and 3) establishment of exploitation levels for these shrimps. Management strategies should include the use of the by-catch, which is composed mostly by other less abundant shrimps (mainly pandalid shrimps), geryonid crabs, deep-sea lobsters, and fishes that could be of commercial importance. Concurrently, it would be recommendable to develop processing and marketing strategies in order to obtain the maximum profit of these potential fishing resources.

The sustainable utilization of this potential deep-water shrimp resource will require reliable information on the biology and ecology of these deep-water shrimp species, especially on mortality and growth rates, life cycle history, and population renewal rates. Initiatives for an ecosystem-based management would be important to minimize possible impacts on the deep-sea ecosystem. This information is critical to define management strategies directed toward a sustainable use of these resources. Finally, we suggest that existing experiences (mainly in Latin America) concerning the responsible use of this deep-water shrimp resource should be consulted and adapted to the present situation in order to help in the development of management strategies that permit a

maximum sustainable yield of this fragile fishing resource while minimizing the environmental impact of this fishery.

## II. CENTRAL AMERICA

**II.1. Introduction.** Central American fisheries targeting crustaceans have focused on shallow water species of the Pacific coast. Information about the exploitation of deep-water decapods is scarce and poorly documented in national fishery statistics; for example, catches of *Heterocarpus* spp. were pooled until 1995 in Costa Rican statistics. Moreover, it seems advisable to interpret with caution the official statistics per country, because they are generally based upon the numbers provided by the fishing industry; there are no established procedures to validate the obtained data and to estimate unreported landings (FAO-OSPESCA, 2006). It might be possible that deep-water shrimps are fished in several countries of the region; however, official reports about these decapods are only available for Nicaragua and Costa Rica. The importance of deep-water shrimp fisheries for the region is difficult to assess; at least in Costa Rica the landings of the three commercially exploited deep-water shrimps (see below) comprised more than 50% of the annual shrimps landings between 1995 and 2005 (Wehrmann & Nielsen-Muñoz, 2006; Álvarez & Ross-Salazar, 2010), but this scenario is most probably not representative for the entire Central American region.

**II.2. Presentation of the species.** Three species are the target of commercial deep-water shrimp fisheries in Central America: the two pandalid species *Heterocarpus vicarius* and *H. affinis*, and the solenocerid shrimp *Solenocera agassizii*.

*Heterocarpus vicarius* Faxon, 1893 (northern nylon shrimp; local name: “camarón camello” or “camarón camellito”) (Fig. 8). This pandalid shrimp is distributed between Gulf of California (Mexico) and Peru (Holthuis, 1980; Hendrickx *et al.*, 1998). This species has been reported between 73 and 760 m, and was caught in traps at depths of up to 1454 m (Hendrickx 1995). According to Holthuis (1980), *H. vicarius* reaches a maximum size of 110 mm total length (TL) and 29 mm carapace length (CL); Hendrickx *et al.* (1998) collected this pandalid shrimp in the southeastern Gulf of California, Mexico, and specimens ranged in size from 10.5 to 33.0 mm CL, but most individuals belonged to the 16–26 mm (CL) size classes. The reproductive biology of *H. vicarius* in Costa Rica has been studied by Echeverría-Sáenz &



**Figure 8.** The northern nylon shrimp *Heterocarpus vicarius*.

**Figura 8.** Camarón camello o camellito *Heterocarpus vicarius*.

Wehrtmann (2011): ovigerous females measured between 29.4 and 45.4 mm CL and carried on average 15,008 newly-extruded eggs. During the incubation period, egg volume increased by 53.3%, while egg mortality during embryogenesis was estimated by 46.9%. Freshly-extruded eggs have an average volume of 0.045 mm<sup>3</sup>, those close to hatching 0.069 mm<sup>3</sup>, which corresponds to an egg volume increase during the incubation period of 53.3%. The average reproductive output was 0.178 and not statistically significant different with female size. Ovigerous females can be found year-round, but are more abundant between June-July and September-October (Wehrtmann & Nielsen-Muñoz, 2009). However, during their August-cruise in 1991, Hendrickx *et al.* (1998) collected only four ovigerous females of *H. vicarius*, and the size of these specimens ranged from 23.3 to 23.9 mm CL.

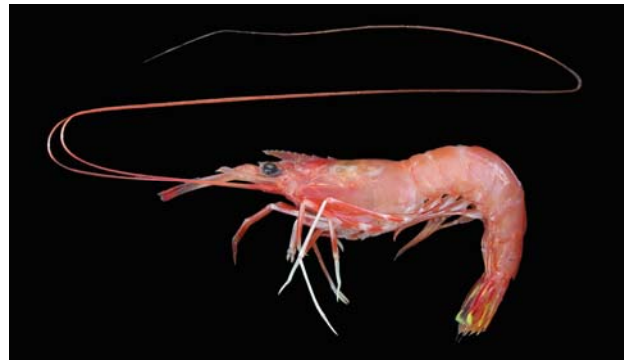
***Heterocarpus affinis*** Faxon, 1893 (three-spined nylon shrimp; local name: “camarón camellón” or “camarón real”) (Fig. 9). Our knowledge about this pandalid shrimp is far from complete. The species is known to occur from the Gulf of California, Mexico, to approximately 8°43'S, Peru (Hendrickx & Wicksten, 1989), and has been collected between 760 and 1240 m depth (Hendrickx & Wicksten, 1989; Hendrickx, 2003). According to Hendrickx (2003), the species can attain a maximum size of 153 mm TL.

***Solenocera agassizii*** Faxon, 1893 (kolibri shrimp; local name: “camarón fidel”) (Fig. 10). The third commercially exploited species in the Central



**Figure 9.** The three-spined nylon shrimp *Heterocarpus affinis*.

**Figura 9.** Camarón camellón o real *Heterocarpus affinis*.



**Figure 10.** The kolibri shrimp *Solenocera agassizii*.

**Figura 10.** Camarón fidel *Solenocera agassizii*.

American region is *S. agassizii*, known to occur from Nicaragua to Peru (see Wehrtmann & Nielsen-Muñoz, 2009). It has been reported from depths between 16 and 350 m (Holthuis, 1980; Hendrickx, 1995), typically associated with mud and sandy-mud bottoms. The species reproduces year-round (Villalobos-Rojas, 2009). Villalobos-Rojas & Wehrtmann (2011) described the ovarian development of this species and found four developmental stages, which can be grouped in “not visible” and “visible” based on the observation of the ovary through the exoskeleton in fresh specimens. Males and females can reach sizes of up to 115 and 154 mm TL, respectively (Hendrickx, 1995; Wehrtmann & Nielsen-Muñoz, 2009).

**II.3. Fishing fleet.** Deep-water shrimps are fished in Central America with bottom trawling nets. The technical details regarding these shrimp trawlers may vary locally; however, the shrimpers typically use the “Florida type” boat with two lateral nets (Fig. 11). These vessels usually have a length of 16 to 24 m (Costa Rica: Álvarez & Ross-Salazar, 2010) and 18 to



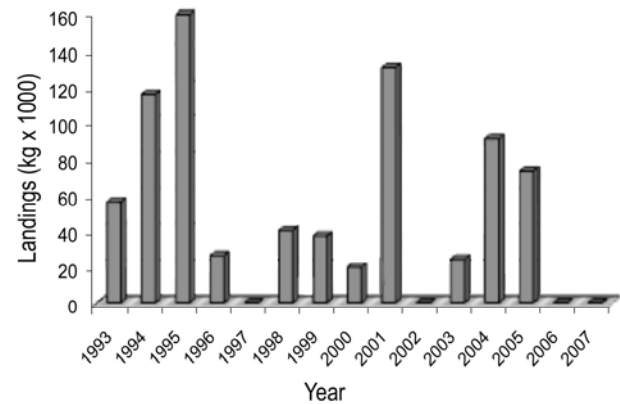
**Figure 11.** Typical “Florida type” shrimp trawler from Costa Rica.

**Figura 11.** Barco arrastrero típico (Tipo Florida) empleado para la pesca de camarones en Costa Rica.

21 m (Nicaragua: INPESCA, 2008), and are powered by an engine of approximately 300 HP. The net has a length a 48 m, and the cod end of the net typically measures 37.7 mm between knots; mesh size in the other parts of the net varies between 40 and 50 mm. The crew consists of 5-6 fishermen, and the duration of each haul may vary between two and five hours. Additional information concerning the characteristics of the semi-industrial shrimp fishery in Costa Rica has been published by Bolaños (2005) and Álvarez & Ross-Salazar (2010).

**II.4. Statistics.** Although deep-water shrimps might be mentioned somehow in national fishery reports, as far as we know, official data are only available from Nicaragua and Costa Rica.

**Nicaragua.** The commercial deep-water fishery is geographically concentrated in the Gulf of Fonseca (13°02'N, 87°48'W) and the Estero Real (12°57'N, 87°25'W), Pacific coast of Nicaragua. The fishery statistics of the Instituto Nicaragüense de la Pesca y Acuicultura (INPESCA) only mention deep-water shrimp as *Heterocarpus* spp., most probably referring to *H. vicarius* and *H. affinis*. According to these statistics (Fig. 12), highest landings were recorded in 1995 with 156,943 kg. However, since 2006 no more landings have been reported (INPESCA, 2008; OSPESCA, 2009). During 1993 and 2007, the number of operating deep-water shrimp trawlers varied between one and three (excluding those years when no boats were fishing).



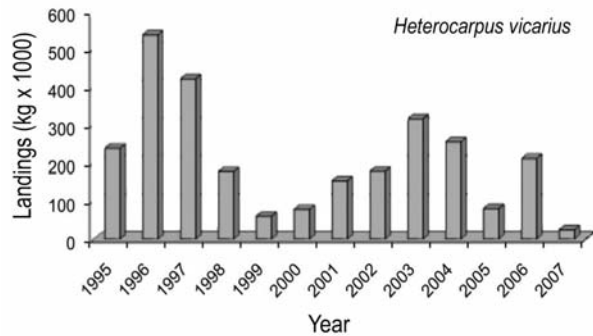
**Figure 12.** Annual landings (1993-2007) of *Heterocarpus* spp. in Nicaragua. Source of information: INPESCA.

**Figura 12.** Desembarques anuales (1993-2007) de *Heterocarpus* spp. en Nicaragua. Fuente de información: INPESCA.

**Costa Rica.** Although being the largest of the three exploited deep-water shrimp species, *H. affinis* plays only a marginal role when considering the annual landings. According to the available statistics of the “Instituto Costarricense de Pesca y Acuicultura” (INCOPECA), commercial exploitation of this shrimp started in 1995, and during the following years landings increased steadily, reaching its highest annual landings in 2003 with 225,277 kg. Thereafter, landings decreased considerably; officially, no landings were reported for 2006, and a total of 69,111 kg for 2007. As far as we know, *H. affinis* is currently fished only in negligible quantities.

Specific information about the reported landings of *H. vicarius* is only available since 1995, because during previous years, INCOPECA combined the data from *H. affinis* and *H. vicarius*, making it impossible to separate the annual production of these two species. Landings peaked in 1996 with 539,101 kg and decreased constantly until 1999 (Fig. 13). Subsequently, reported landings increased steadily until 2003 (316,745 kg), but thereafter catches decreased again; landings in 2007 reached 25,073 kg, currently representing the last value available from INCOPECA. According to our information (R. Diers, The Rainbow Jewels S.A., Puntarenas; *pers. comm.*), landings during 2008 and 2010 remained on very low levels.

The solenocerid shrimp *Solenocera agassizii* can be considered as the most important shrimp in the commercial deep-water shrimp fishery in Costa Rica (Wehrmann & Nielsen-Muñoz, 2009). Annual landing of this species represented 27% (1995-2000) and 29% (2001-2006) of the total shrimp landings in



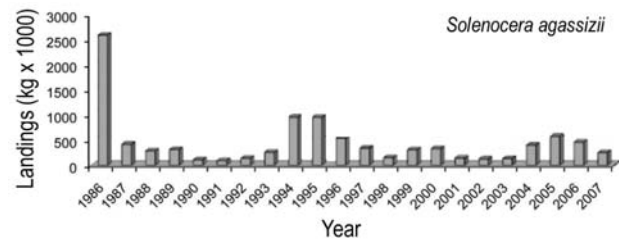
**Figure 13.** Reported landings of *Heterocarpus vicarius* from Pacific Costa Rica, 1995-2007. Source of information: INCOPECSA.

**Figura 13.** Registro de desembarques de *Heterocarpus vicarius* capturados frente a la costa Pacífica de Costa Rica, 1995-2007. Fuente de información: INCOPECSA.

Costa Rica. By far, the highest annual landings ( $2.6 \times 10^6$  kg), were reported in 1986 (Fig. 14). The next but substantially lower peak ( $0.9 \times 10^6$  kg), was observed between 1994 -1995. Subsequently, catches dropped again and increased only after 2003, probably related to the fishing activities of The Rainbow Jewels S.A., a company, especially interested in this resource. The official statistics seem to indicate peak landings roughly every 10 years, however, always on lower levels.

**II.5. Bycatch and discards.** As far as we know, Costa Rica is the only Central American country with information about the bycatch and discards associated with the deep-water shrimp fishery. In general, the entire bycatch is discarded, including squat lobsters (*Pleuroncodes monodon*), which are the target of a commercial fishery in other regions (Wehrtmann & Acuña, 2011). Several attempts to convince local fishermen and companies to utilize this resource in Costa Rica have not yet been successful.

Wehrtmann & Echeverría-Sáenz (2007) analyzed the crustacean fauna associated with the deep-water shrimp fishery (*H. vicarius* and *S. agassizii*) along the Pacific coast Costa Rica: three species dominated the bycatch, namely *Squilla biformis* Bigelow, 1891 (Squillidae), *Plesionika trispinus* Squires & Barragan, 1976 (Pandalidae), and *Pleuroncodes monodon* H. Milne Edwards, 1837 (Galatheididae). More recent data (Fig. 15) indicated that *S. biformis* and fishes remained to be the predominant bycatch, while the pandalid shrimp *P. trispinus* practically disappeared from the catches since 2006. During 2008-2010, the squat lobster *P. monodon* was substantially less abundant when compared to the years 2004 and 2007.

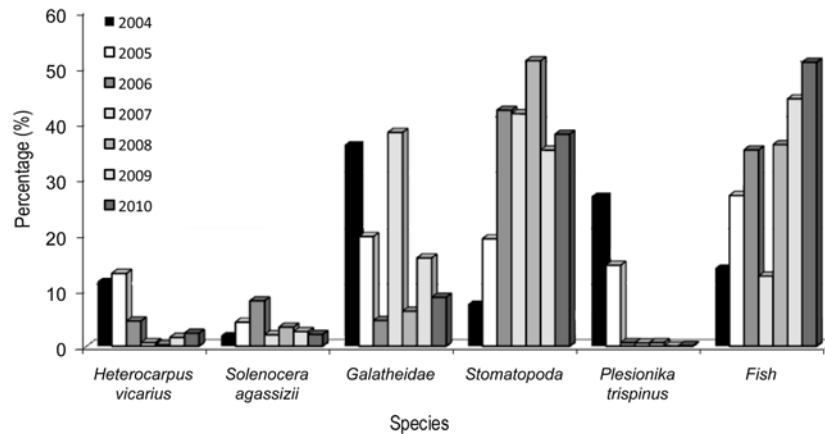


**Figure 14.** Reported landings of *Solenocera agassizii* from Pacific Costa Rica, 1986-2007. Source of information: INCOPECSA.

**Figura 14.** Registro de desembarques de *Solenocera agassizii* capturados frente a la costa Pacífica de Costa Rica, 1986-2007. Fuente de información: INCOPECSA.

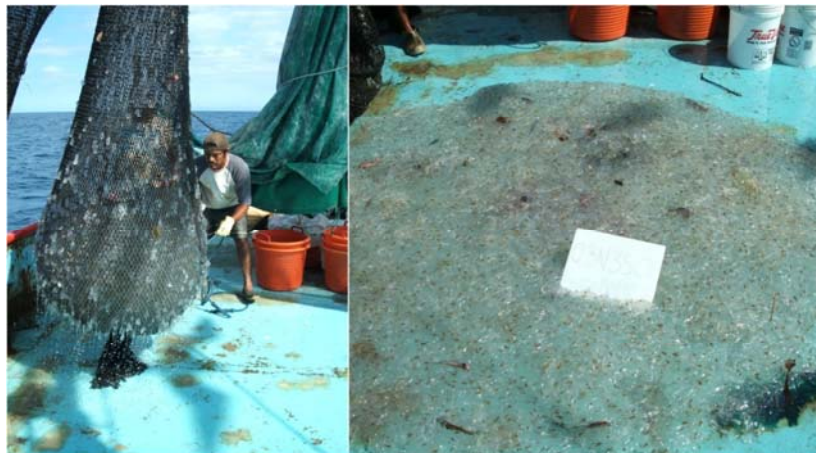
Interestingly, a research cruise carried out in March 2011 covering the entire Pacific coast of Costa Rica revealed the massive presence of siphonophores in the trawling nets fishing at depths between 150 and 350 m (Fig. 16). This finding may indicate significant changes in this fishery-based ecosystem, where trawling may have eliminated filter and detritus feeders, increasing scarcity of organisms feeding on phytoplankton and marine snow (see Pauly *et al.*, 2009). It is speculated that such a condition may have favored the siphonophore outbreak observed along the Pacific coast of Costa Rica. The sudden massive appearance of “jellyfish” requires further attention.

**II.6. Conclusions.** In Central America, deep-water shrimps are currently commercially exploited only in Nicaragua and Costa Rica. To the best of our knowledge, neither country has implemented a management plan for the deep-water resources. Due to the decreasing landings and increasing costs, more and more companies leave their trawlers in the harbor. This may favor the recovery of the stressed deep-water habitats, but will provoke also considerable social and economic consequences. The introduction of fishing restrictions and the implementation of a management plan, based on solid scientific data, seems to be indispensable to prevent the complete collapse of the shrimp resources (see Wehrtmann & Nielsen-Muñoz, 2009; Álvarez & Ross-Salazar, 2010). In this context, it is strongly recommended to improve collaboration between all relevant stakeholders (*e.g.* fishing sector, governmental sector, academic sector), thus facilitating information exchange regarding deep-water shrimp resources in order to support adequate decisions concerning fishing regulations at a national and regional level.



**Figure 15.** Bycatch composition of the commercial deep-water shrimp fishery in Pacific Costa Rica, 2004-2010 (I.S. Wehrmann, unpublished data).

**Figura 15.** Composición de la fauna acompañante de la pesca comercial de camarones de aguas profundas frente a la costa Pacífica de Costa Rica, 2004-2010 (I.S. Wehrmann, datos no publicados).



**Figure 16.** Mass occurrence of siphonophores in a deep-water shrimp haul carried out off Pacific Costa Rica, March 2011 (Photo: Tayler McLellan Clarke).

**Figura 16.** Masa de sifonóforos obtenida en un lance de pesca dirigida a la captura de camarones de aguas profundas frente a la costa Pacífica de Costa Rica, marzo 2011 (Foto: Tayler McLellan Clarke).

### III. PERU

**III.1. Introduction.** Before the mid 1960s, it was assumed that the benthic and benthopelagic fauna off the Peruvian coast was poor, mostly probably due to the observed oxygen deficiency (Schweigger, 1943; Popovici, 1963), which supposedly prevented the presence of commercially interesting aggregations of groundfish. However, results published by Del Solar *et al.* (1965) revealed a rich biocenosis in deep-water environments off Peru, characterized by low oxygen contents with Peruvian hake (*Merluccius gayi peruanus*) as the characteristic and indicator species. Since the 1960s, a hake trawl fishery was developed, becoming one of the most important fisheries in Peru

(Wosnitza-Mendo *et al.*, 2007; Guevara-Carrasco & Leonart, 2008).

An exploratory and experimental deep-water fishing using nontraditional gears and fishing methods was developed in 2001, revealing the presence of king crabs (Lithodidae) off Callao (12°S). These crabs were considered as a potential and alternative resource for a nontraditional trap fishery (Salazar *et al.*, 2001). Thus, in 2003 a trap fishery for king crab *Paralomis longipes* began, reaching a maximum yield of 9.4 ton in June 2008; during 2009 and 2010 landings of this king crab fishery declined considerably (S. Aguilar, IMARPE, *pers. comm.*).

The Patagonian toothfish (*Dissostichus eleginoides*) is the target of another deep-water fishery in



Peru carried out by a small fleet (5-6 boats) using longlines. This species is included in the Peruvian landing statistics since 1995 (Sancho, 2002). Fishing takes place along the Peruvian coast, from Salaverry (08°S) to Ilo (18°S), and at depths between 1000 and 1500 m. In recent years (2005 to 2010) the average yearly landing was of 130.3 ton (V. Aramayo, IMARPE, *pers. comm.*).

Since the middle 1960's, the Peruvian Marine Research Institute (IMARPE) has carried out research cruises along the Peruvian coast to investigate the archibenthic and bathyal fauna. The results of these cruises revealed the presence of more than 250 species and contributed significantly to our knowledge on the deep-water fauna (Del Solar & Álamo, 1970; Del Solar & Mistakidis, 1971; Vilchez *et al.*, 1971; Del Solar & Flores, 1972; Kameya *et al.*, 1997; JDSTA-IMARPE, 2004; Barriga *et al.*, 2009). The following species of deep-water shrimps stand out due to their wide distribution and abundance in Peruvian waters: *Haliporoides diomedea*, *Benthescymus tanneri*, *Nematocarcinus agassizii*, *Heterocarpus vicarius*, *H. hostilis*, and *Pasiphaea magna*. Several studies were carried out to describe the biology and population dynamic of these decapods in order to generate enough information to promote sustainable fisheries targeting these potential resources (Méndez, 1981; Kameya *et al.*, 1997; Barriga *et al.*, 2009).

More recently (between 2007 and 2010), four research cruises were carried out by IMARPE, with the Spanish research vessel “Miguel Oliver”, to characterize the principal faunal components of the benthic-demersal subsystem of the bathyal and archibenthic zones (between 200 to 1500 m depth) off the Peruvian coast from Puerto Pizarro (03°30'S) to Morro Sama (18°00'S). A bottom trawl (randomly stratified sampling) and the swept area method were applied to determine the distribution and relative abundance of the fauna (Alverson & Pereyra, 1969; Espino & Wosnitza-Mendo, 1984; Sparre & Venema, 1995). The total area was divided in eight zones (two zones per cruise) and three depth strata (200 to 500 m, 500 to 1000 m, and 1000 to 1500 m depth). A total of 272 hauls (30 min of effective trawling) were carried out with a mean speed of approximately three knots using a bottom net type LOFOTEN (for details see Barriga *et al.*, 2009). The following sections synthesize the principal results concerning the distribution and abundance of deep-water shrimps in Peruvian waters.

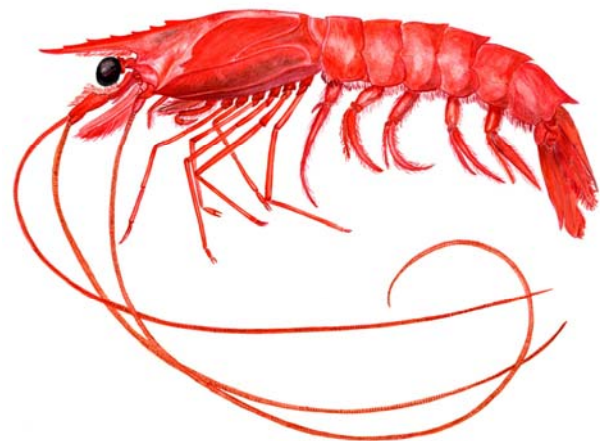
### III.2. Presentation of the species

***Haliporoides diomedea*** Faxon, 1893 (red royal shrimp; local names: “gamba” in Chile, “langostino

rojo de profundidad” or “gamba roja” in Peru) (Fig. 17). Details concerning the morphological characteristics of the species were described by Pérez-Illanes & Zúñiga (1972), Farfante (1977) and Méndez (1981). This species, from the Panamanian and Chilean-Peruvian marine zoographic provinces, has been recorded from the Gulf of Panama (07°10'N) to Chiloé Island in Chile (42°30'S), representing a distance of more than 4,500 km along the Pacific coast of South America (Bahamonde, 1963; Chirichigno, 1970; Noziglia & Arana, 1976; Pérez-Farfante, 1977; Arana *et al.*, 2003b, 2003c) (Fig. 18). The species prefers soft and muddy bottoms (Mistakidis & Henríquez, 1966; Del Solar & Mistakidis, 1971; Vilchez *et al.*, 1971; Del Solar & Flores, 1972; Noziglia & Arana, 1976). Relatively high abundances of *H. diomedea* seem to be associated to large river mouths such as the Guayas River (Ecuador), rivers of the northern coast of Peru (Banco de Máncora), and off Maipo and Bío-Bío rivers in the central-southern coast of Chile.

The bathymetric distribution of *H. diomedea* changes with latitude, with a distinct deepening from south to north. The presence of the species, at large depths, may be related to the physical characteristics of the Antarctic Intermediate Water (AAIW), where the temperature oscillates between 7.5°C and 3.5°C. It is assumed that a reverse relationship exists between the species abundance and the intensification of these water mass in the southeastern Pacific (Noziglia & Arana, 1976).

All investigations have indicated *H. diomedea* as the most important deep-water shrimp in Peru due to several reasons: (1) its wide distribution and abun-



**Figure 17.** The red royal shrimp *Haliporoides diomedea*.

**Figura 17.** Gamba o langostino rojo de profundidad *Haliporoides diomedea*.



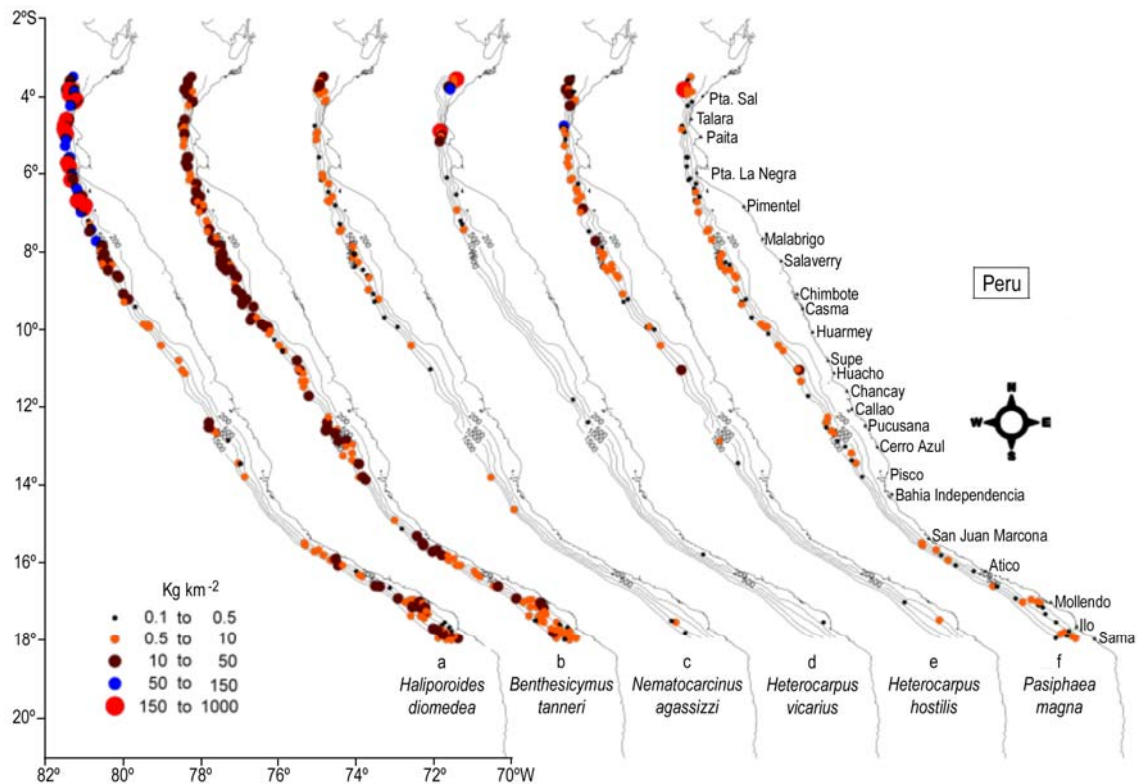


**Figure 18.** Distribution ranges of *Haliporoides diomedea* in the Pacific Ocean.

**Figura 18.** Rango de distribución de *Haliporoides diomedea* en el océano Pacífico.

dance, (2) being a key component in the benthodemersal community, and (3) its potential for the development of a commercial fishery, mainly off the northern coast of Peru (Del Solar & Álamo, 1970; Vélez *et al.*, 1992; Kameya *et al.*, 2006). In Peru, *H. diomedea* is widely distributed between 600 and more than 1500 m deep. Three areas of high abundance were detected: (1) north of 08°S (Malabrigo), where the highest biomass was observed in concentrations around 50 and more than 150 kg km<sup>-2</sup>, (mean about 139 kg km<sup>-2</sup>, especially in hauls deeper than 600 m); (2) the area between 08°S (Malabrigo) and 16°S (San Juan de Marcona); in this zone, between 08°S and 09°S, the species was present in low abundances (16 kg km<sup>-2</sup>) and almost absent in the remaining area; (3) south of 16°S, where *H. diomedea* was found to be present in low abundances (mean biomass was 8.7 kg km<sup>-2</sup>), mainly between 700 y 1200 m depth (Fig. 19).

*Benthescymus tanneri* Faxon, 1893 (red royal shrimp; local name: “gamba” in Chile, “langostino rojo de profundidad” or “gamba roja” in Peru). Méndez (1981) described morphological characteristics of this species from Peruvian material. *B. tanneri* is known to occur in Gulf of California, Panama, Colombia, Galapagos Islands, Ecuador and Peru. This species is soft and fragile, and rarely arrives at the surface intact. So, it would be a poor candidate for a fishery. Male and female shrimps collected on the continental slope off Peru ranged in size between 13.5-25.0 mm and 11.0-30.7 mm CL, respectively (Méndez, 1981). The results of our recent studies (2007-2010) confirm a wide distribution of *B. tanneri* in Peruvian waters between 600 and 1500 m depth; mean biomass was estimated to be 9.2 kg km<sup>-2</sup>, and the areas of highest concentrations were located north of 10°S (Huarney) (Fig. 19).



**Figure 19.** Distribution and relative biomass ( $\text{kg km}^{-2}$ ) of six deep-water shrimps off the Peruvian coast. Data come from four research cruises carried out between 2007 and 2010 with the R/V “Miguel Oliver”.

**Figura 19.** Distribución y abundancia relativa ( $\text{kg km}^{-2}$ ) de seis camarones de aguas profundas frente a la costa de Perú. Datos obtenidos en cuatro cruceros de investigación realizados entre 2007 y 2010 con el R/V “Miguel Oliver”.

*Nematocarcinus agassizii* Faxon, 1893 (local name: “camarón rojo de profundidad”). This deep-water shrimp belongs to the family Nematocarcinidae and it is adapted to walk on the soft bottom seafloor covering the continental slope (Méndez, 1981). Morphological characteristics of Peruvian specimens were described by Méndez (1981), and the size of males and females collected by IMARPE varied between 17.2-20.2 mm CL and 17.4-26.0 mm CL, respectively.

Scientific cruises carried out between 2007 to 2010 revealed the presence of *N. agassizii* in the northern zone (Fig. 19), with highest abundances off Tumbes (until  $04^{\circ}10'S$ ) between 500 and 800 m depth: the mean biomass was around  $12 \text{ kg km}^{-2}$ , ranging from 0.5 to  $45 \text{ kg km}^{-2}$ . The southern boundary was observed to be located off Chimbote ( $11^{\circ}S$ ). A few individuals were observed also off Ilo ( $17^{\circ}30'S$ ), thus expanding the geographic distribution reported by Méndez (1981); she indicated the limit at  $16^{\circ}30'S$  based on observations published by Del Solar & Flores, 1972).

*Heterocarpus vicarius* Faxon, 1893 (northern nylon shrimp; local name in Peru: “camaron rojo de profundidad” or “camaron nylon”) (Fig. 8). The geographic distribution of this pandalid shrimp extends from the Gulf of California to southern Peru (Méndez, 1981). In Peru, this benthic shrimp inhabits the continental slope between Banco de Mancora ( $03^{\circ}24'S$ ) and Mollendo ( $17^{\circ}S$ ); its vertical distribution ranges from 383 to 800 m (Méndez, 1981). Results of our scientific cruises carried out between 2007 and 2010 indicated highest biomass in areas north of Paita ( $05^{\circ}00'S$ ) at depths below 500 m, where the biomass was generally higher than  $50 \text{ kg km}^{-2}$  with a mean of  $125 \text{ kg km}^{-2}$ . South of Paita the species was less abundant ( $<0.5 \text{ kg km}^{-2}$ ), and few individuals were collected off Ilo ( $17^{\circ}37'S$ ), probably indicating the southern border of its distribution in Peruvian waters (Fig. 19).

*Heterocarpus hostilis* Faxon, 1893 (local name: “camarón nailon”). This pandalid shrimp is distributed from Gulf of Panama to Isla del Coco in Peru. Del Solar (1972) reported the species in Peru

from 3°30'S to 10°5'S, occurring at depths between 695 and 800 m. Morphological characteristics of *H. hostilis* in Peru are described by Méndez (1981). The results of the scientific cruises carried out between 2007 and 2010 (Fig. 19) showed that the species is common and abundant (between 0.5 and 50 kg km<sup>-2</sup>) north of 11°00'S (Huacho), mainly concentrated in depths over 1000 m.

***Pasiphaea magna*** Faxon, 1893 (local name in Peru: “camarón vidrio”). Morphology, distribution and commercial importance in Peru were described by Méndez (1981). This shrimp is a pelagic species, which occurs as “accidental catch” in benthic trawls. The species is distributed along the Peruvian coast, inhabiting bathyal and archibenthic zones between 600 m and 1500 m. According to the results of the scientific cruises (2007-2010), this shrimp is not very abundant (mean biomass was 1.3 kg km<sup>-2</sup>), with the exception of an area off Tumbes (north of 04°00'S), where biomass values reached up to 50 kg km<sup>-2</sup> (Fig. 19).

**III. 3. Fisheries, actual status of resources and perspectives.** So far, no commercial deep-water shrimp fishery has been implemented in Peru. Therefore, the six potentially exploitable resources described above are virtually in pristine conditions, not subject to fishing pressure. Small amounts of these shrimps are accidentally caught as by-catch by industrial trawlers operating in northern Peru. Future strategies to begin any commercial exploitation of these species should consider the ecosystem approach, especially in northern Peru where the highest abundances and the greatest biological diversity of the benthic-demersal subsystem in Peruvian waters has been found.

#### IV. CHILE

**IV.1. Introduction.** After World War II, Chile experienced a remarkable development of its fisheries, which reached record landings exceeding 8 million ton by 1994. Although most captures involved pelagic fish species, benthic crustaceans inhabiting coastal areas or the continental shelf, such as crabs (*Cancer* spp., *Homalaspis plana*), yellow squat lobster (*Cervimunida johni*) and red squat lobster (*Pleuroncodes monodon*) were also extracted.

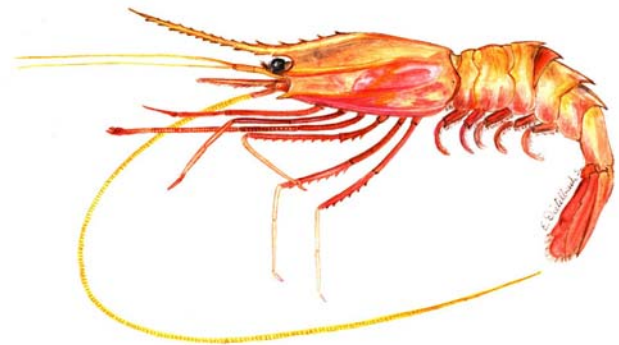
Since the mid-1900s, and with the arrival of larger and more powerful trawlers, offshore fishing operations started to be conducted along the Chilean coast. At the same time, the exploitation of the nylon shrimp (*Heterocarpus reedi*) began, achieving a record of 72,194 ton of landed shrimps in 1976. Nylon shrimp landings subsequently and progressively

decreased, which promoted the search of new resources by researchers and companies, especially towards deeper waters. Besides the nylon shrimp, two other shrimp species with potential for a commercial exploitation were found in deep waters: the red royal shrimp (*Haliporoides diomedea*) and the razor shrimp (*Campylonotus semistriatus*). These three species have been intensively studied, and the present review summarizes the obtained results.

Landing statistics for the last five years showed that the national extraction of decapod crustaceans have ranged between 20,000 and 25,000 ton yr<sup>-1</sup>; the deep-water decapods, living in waters exceeding the 200 m depth, represent between 25% and 30% of the total catches of this taxonomic group (SERNA-PESCA, Anuarios Estadísticos de Pesca, Chile 2005-2010; www.sernapesca.cl).

**IV.2. *Heterocarpus reedi*** Bahamonde, 1955 (Chilean nylon shrimp: local name: “camarón nylon”) (Fig. 20). The morphological characteristics of the species have been described by Bahamonde (1955), Illanes & Zúñiga (1971) and Retamal (2000).

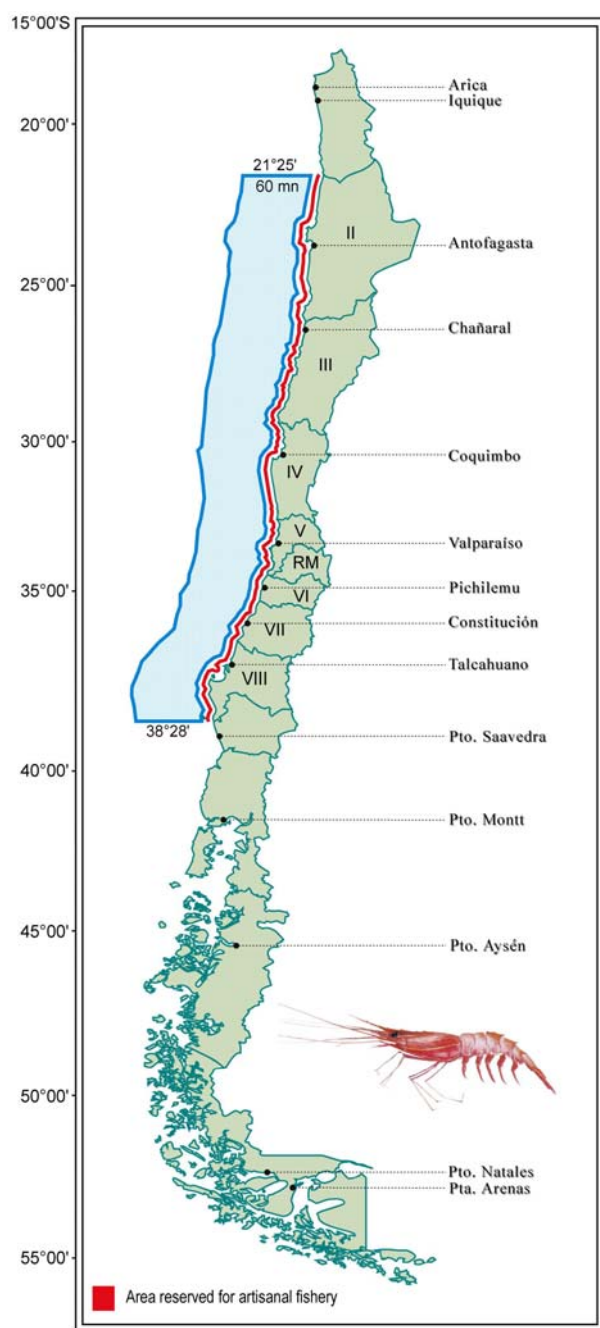
**IV.2.1. Distribution.** The geographical distribution of *H. reedi* comprises the area off central-northern to central-southern Chile, between 23°48'S (south of Antofagasta) and 39°00'S (Puerto Saavedra). Moreover, the presence of *H. reedi* has also been reported offshore Peru (Vílchez *et al.*, 1971). In Chile, the spatial coverage between Antofagasta (23°30'S) and Coquimbo (30°30'S) is almost continuous. In contrast, the presence of the resource is scattered in the southern part of its distribution, forming small patches towards the north and south of the Río Maipo Canyon in the O'Higgins Region (33°30'S) and off Punta Nugurne in the Maule Region (35°55'S). Therefore, the fishing fleet has been operating mainly



**Figure 20.** The Chilean nylon shrimp *Heterocarpus reedi*.

**Figura 20.** Camarón nylon chileno *Heterocarpus reedi*.

between Chañaral and Talcahuano (Fig. 21). For descriptive and administrative purposes, the fishery of *H. reedi* is divided into two different macro-zones: the northern macro-zone (between 21°25'S and 32°10'S; Antofagasta, Atacama and Coquimbo regions) and the southern macro-zone (between 32°10'S and 38°28'S; Valparaíso, O'Higgins, Maule and Bio Bio regions).



**Figure 21.** Fishing areas of *Heterocarpus reedi* in Chile.

**Figura 21.** Áreas de pesca de *Heterocarpus reedi* en Chile.

The nylon shrimp lives in the continental slope at depths ranging between 155 and 800 m (Yáñez, 1973, 1974; Yáñez & Barbieri, 1974). *Heterocarpus reedi* occurs in an area where Subsurface Equatorial Water (ESSW) and Antarctic Intermediate Water (AAIW) mix between 200 and 500 m. According to Arana & Nakanishi (1971) and Arana *et al.* (1975), the depth changes of these water masses and the upwelling processes observed alongshore the Chilean coast promote the depth-related movement of this resource perpendicular to the coast. As suggested by the same authors, ovigerous females move towards shallower waters to release their larvae and later return to deeper waters. However, the nylon shrimp fisheries operate mainly at depths between the 150 and 500 m.

**IV.2.2. Habitat.** This shrimp is generally found on mud bottoms, sedimentary rock, muddy sands and sandstone. According to Acuña *et al.* (2009), 70% of the observations correspond to catches over fine sand and 25.7% over medium sand grain.

**IV.2.3. Life history parameters.** The species presents sexual dimorphism, which is externally not evident. The embryonic development and reproductive potential have been studied by different authors (Bahamonde, 1958; Bahamonde & López, 1960; Palma, 1996; Palma & Ulloa, 1998; Wehrtmann & Andrade, 1998, Acuña *et al.*, 2003). The nylon shrimp produces between 1,912 and 27,237 eggs in females among 22 and 38 mm of CL (Arana *et al.*, 1976; Wehrtmann & Andrade, 1998). The mean size at maturity is reached between 21.3 and 26.4 mm CL (3.5-4.5 yr approximately) (Arana *et al.*, 1976; Acuña *et al.*, 2003).

The presence of ovigerous females extends from April to December (Arana & Tiffou, 1970; Arana *et al.*, 1976); almost 100% of females carry eggs under the abdomen between May-November (Arana *et al.*, 1976), and the release of their larvae occurs towards late winter and early spring (September-November), involving densities that may exceed 200 larvae per 1000 m<sup>3</sup> (Gálvez, 1997; Roa *et al.*, 1999; Acuña *et al.*, 2007a).

Females grow larger than males; maximum sizes correspond to 43 and 40 mm CL for females and males, respectively (Arana *et al.*, 1976; Roa & Ernst, 1996).

In general, the global sexual proportion shows a female predominance (57%) over males (43%) (Arana *et al.*, 1976). Females are predominant among individuals smaller than 20 mm CL, while males prevail in size classes between 20 and 25 mm CL; finally, in sizes >25 mm CL, females become progressively



more abundant until reaching 100% in specimens measuring >34 mm CL (Gaete & Arana, 1986).

According to Arana *et al.* (1976), the principal molting periods include March-May, July-September and November-January, a feature that may be associated to variations of the condition factor (Yany, 1974) and the chemical composition of the abdominal muscle. The molting increase varies between 9.7-10.6% and 7.2-8.9% in females and males, respectively (Arana *et al.*, 1976).

Growth of *H. reedi* has been studied by Ziller (1993), who established the following growth parameters:  $L_{\infty}$ =37.67 mm CL;  $k$ =0.343 y  $t_0$ =-0.117 in males and  $L_{\infty}$ =43.87;  $k$ =0.305 and  $t_0$ =-0.17 in females. Roa & Ernst (1996) pointed out that the exploited fraction of the *H. reedi* population is comprised of five different annual classes, with clearly distinctive growth parameters between sexes, and values of  $L_{\infty}$ =40.68;  $k$ =0.199 and  $t_0$ =-0.809 for males and  $L_{\infty}$ =48.34 mm CL;  $k$ =0.174 and  $t_0$ =-0.51 for females.

The catch composition varies with zone and depth, where *H. reedi* is fished (Andrade & Báez, 1980; Acuña *et al.*, 2005; Orellana, 2006). In general, the main by-catch species in the northern macro-zone are the red squat lobster (*Pleuroncodes monodon*), yellow squat lobster (*Cervimunida johni*), spider crab (*Lophorochinia parabranchia*), common hake (*Merluccius gayi gayi*), bigeye flounder (*Hippoglossina macrops*) and Aconcagua grenadier (*Coelorinchus aconcagua*) and Chilean rattail (*C. chilensis*). In the southern macro-zone, on the other hand, the main components of the bycatch are: the common hake, yellow squat lobster, spider crab (*Libidoclaea granaria*), bigeye flounder and Aconcagua grenadier. The catch index revealed that the by-catch averages 1.5 kg per kilogram of nylon shrimp (Orellana, 2006). The nylon shrimp represents a weight average of 81.8% of the total commercial catch (Zilleruelo & Parraga, 2009).

The shrimp shows a detritivorous diet with an omnivorous regime, mainly characterized by sediments, Foraminifera, sponges, gastropods, Ophiuroidea and decapod remains (Báez & Andrade, 1980).

The main predators of this species include the bigeye flounder (*Hippoglossina macrops*) (see Acuña *et al.*, 2007a), the Patagonian toothfish (*Dissostichus eleginoides*) (see Flores & Rojas, 1987), the kingklip (*Genypterus blacodes*) (see Andrade, 1986) and the common hake (*Merluccius gayi gayi*) (see Hoyl, 1967).

**IV.2.4. Fisheries gear.** Polyamide bottom trawling net with metallic gangways and 5 cm uniform meshes

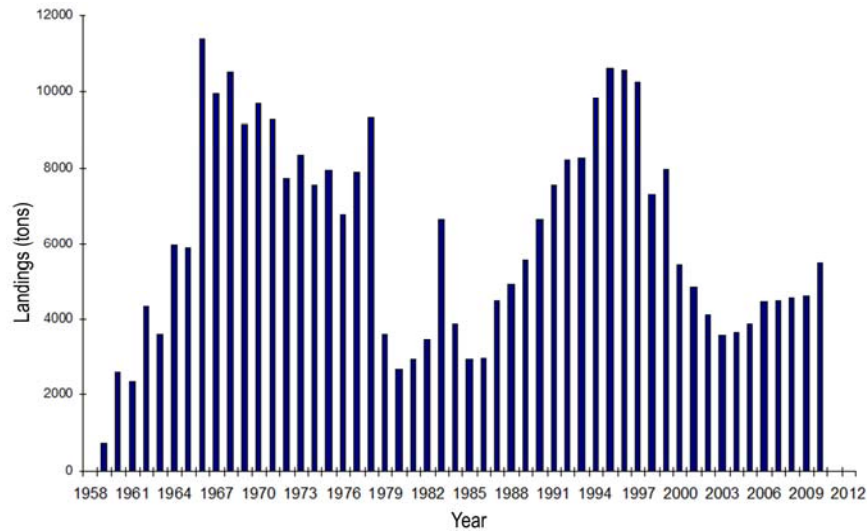
(2 inches), similar to those used in Chilean knife shrimp (*Haliporoides diomedea*) fisheries are employed in the commercial fisheries of *H. reedi*.

Selectivity studies of trawling nets (considering the mean size at first maturity of 25 mm CL in females) revealed that mesh size should be at least 59 mm (2.5") to protect 50% of the females; such mesh size would slightly "overprotect" males as they show smaller sizes and would probably mature earlier (ECM, 2000a).

**IV.2.5. Fishery statistics and management.** The nylon shrimp sustains the main shrimp fisheries in Chile, regularly exploited by industrial and artisanal fishery fleets. The commercial exploitation of this resource started in the 1950s as by-catch of the common hake fishery (*Merluccius gayi gayi*); subsequently it became a significant target resource as landing exceeded the 11,000 ton in 1968. Thereafter, a progressive decrease in the landing levels was observed, reaching 2,700 ton in 1980, to remain stable for a period of seven years around 3,000 ton. During the next years, a sustained increase in landing was observed until 1995-1996, when they once again exceeded 10,000 ton yr<sup>-1</sup> (Fig. 22).

By late 1994, the nylon shrimp fisheries were subjected to a general access regime (i.e. free access). In 1995, it was declared as in a Full Exploitation State and regime. At the same time the fishing unit of the nylon shrimp (*H. reedi*) was defined as the fishing area covering the coast between the northern limit of Antofagasta (21°25'S) and the southern limit of Bio-Bio (38°28'S), from the eastern limit five miles offshore to the western limit corresponding to an imaginary line drawn at a 60-mile distance (Decree MINECOM N°611 of 1995). This measure implicated the establishment of a global annual fishing quota, and the closure of the fisheries register for new applications for vessels and fishermen. Additionally, a biologically-based seasonal closure was established in the entire fishing area, from 01 July to 31 August of each calendar year. During the closed season it was forbidden to catch, market, transport, process and store the banned species and its derived products (SUBPESCA Decree N°92 of 1998).

Subsequently in 2001, the fisheries were subjected to the Maximum Catch Limit per ship-owner, which involved the annual distribution of the global annual catch quota allocating 80% to the industrial sector (divided among ship-owners with valid fishing permits to execute extractive activities) and the remaining 20% to the artisanal sector. In addition to the latter measures, since 2003 the global fishing quota was divided per administrative region in order



**Figure 22.** Annual landings of nylon shrimp (*Heterocarpus reedi*) in Chile. Source of information: SERNAPESCA.

**Figura 22.** Desembarques anuales de camarón nailon (*Heterocarpus reedi*) en Chile. Fuente de información: SERNAPESCA.

to avoid the concentration of fishing efforts and adapt the amount to be extracted according to the resource availability. Likewise, and aiming to achieve a year-round exploitation, the quota assigned to each region was subdivided into three periods: January-March, April–August and September-December.

Once the status of this fishery changed, quotas of 10,000 ton were established for 1996 and 1997, which were later reduced to 8,300 ton yr<sup>-1</sup> (1998) and 7,900 ton yr<sup>-1</sup> (1999). Since 2000, the global annual quotas have remained between 4,000 and 5,000 ton yr<sup>-1</sup> (2010) (Table 2). A 5,200 ton quota has been set for 2011 (SUBPESCA, 2010).

A total of 26 industrial trawlers (Fig. 23) and five artisanal boats have been traditionally operating for this fishery, which executed nearly 2,500 hauls per year, with a mean duration of 2.5 h each. The yield has reached values close to 300 kg of nylon shrimp per trawling hour (t.h.) in the northern macro-zone, over 400 kg t.h<sup>-1</sup> in the southern macro-zone with an average of nearly 350 kg t.h<sup>-1</sup> (Zilleruelo & Párraga, 2009).

**IV.2.6. Current situation of the resource.** Since 1998, the nylon shrimp has been periodically studied through monitoring surveys (Acuña *et al.*, 1999, 2000a, 2001), indirect stock assessment (Acuña *et al.*, 1997b; Canales *et al.*, 1998), and direct assessment cruises to determine the biomass vulnerable to trawling gears using the catch swept area method (Acuña & Arancibia, 1996; Pavez, 1996; Roa *et al.*,

**Table 2.** Nylon shrimp (*Heterocarpus reedi*) landings and annual global quota in Chile

**Tabla 2.** Desembarque y cuota global anual de camarón nailon (*Heterocarpus reedi*) en Chile

Year	Catch landings (ton)			Annual quota (ton)
	Artisanal	Industrial	Total	
1998	764	6,537	7,301	8,300
1999	1,186	6,765	7,951	7,900
2000	1,220	4,228	5,448	5,000
2001	1,006	3,856	4,862	5,000
2002	948	1,949	2,897	4,800
2003	1,000	2,589	3,589	4,800
2004	943	2,720	3,663	4,770
2005	544	3,196	3,740	5,130
2006	713	3,617	4,330	5,130
2007	703	3,637	4,340	5,130
2008	797	3,760	4,557	5,200
2009	847	3,647	4,494	5,200
2010	900	3,450	4,350	5,500
2011				5,200

Source of information: SERNAPESCA

1999; Acuña *et al.*, 2000b, 2002, 2007b, 2009; ECM, 2000b; Arana *et al.*, 2003a, 2004, 2005, 2006).

During the last ten years, a gradual change of the available biomass of the resource has been observed: from 10,000 ton in 1998 to a reported biomass oscillating between 28,000 and 30,000 ton in 2008





**Figure 23.** Industrial trawler used in Chile for the crustacean fisheries.

**Figura 23.** Barco arrastrero industrial utilizado en las pesquerías chilenas de crustáceos.

(Table 3). Consequently, Canales & Arana (2010) demonstrated that the catch per unit area (CPUA) increased from 532 kg km<sup>-2</sup> in 1998 to more than 4,000 kg km<sup>-2</sup> in 2006. This shows that the implementation of low catch quotas for this fishery has achieved a gradual recovery of the species, equivalent to an exploitation rate of 15% in the last year (Acuña *et al.*, 2009). The implementation of global catch quotas below 5,000 ton would maintain the *status quo* situation for the exploitation of *H. reedi*, contributing to the maintenance and recuperation and thus avoiding overexploitation of the resource.

**IV.2.7. Commercialization.** Nylon shrimp catches are used for different marketing processes. The main process is freezing (peeled-tails, IQF), followed by fresh-chilled and dehydratation. Production excesses (carapace, appendix and exoskeletons) are used in flour production. Top-quality product volumes in the industry have remained between 700-850 ton yr<sup>-1</sup> during the last years. The most significant markets for frozen products are Germany (44%), Japan (24%), Taiwan (15%), Denmark (8%) and UK (5%); the remaining 4% goes to different locations. Local markets offer fresh unpeeled shrimp tails.

**IV.2.8. Conclusions.** Although a significant recovery of the nylon shrimp biomass has been observed, during the past 10 years the stock still has not consolidated at catch levels over 5,000 ton yr<sup>-1</sup>. A better chance of recovery may be achieved with annual catches lower than the aforementioned, thus allowing an increase in the current biomass and achieve exploitation rates of the order of 10%.

### IV.3. *Haliporoides diomedae* (Faxon, 1893) (Fig. 17)

**IV.3.1. Distribution and life history characteristics in Chile.** *Haliporoides diomedae* is distributed through a continuous “band” in the central area of Chile, occasionally interrupted by topographic features (San Antonio submarine canyon, 33°31’S) or non suitable areas for trawling such as Punta Duao (34°48’S) and Constitución-Carranza (35°11’-35°34’S). The species can be found between 400-1000 m off central Chile (Arana *et al.*, 2003b) and in the southernmost area between 500-900 m (Leiva *et al.*, 1997). Red royal shrimp concentrations during exploratory fishing were found to be associated with the approximate depth location of the 5°C isotherm (Noziglia & Arana, 1976). The species lives semi-buried in soft bottoms and associated with different decapods and fish species (Zilleruelo & Párraga, 2009). According to data obtained from the Chilean fisheries, *H. diomedae* represents 52% of the weight catch in commercial hauls (Zilleruelo & Párraga, 2009).

The following species have been reported to prey on *H. diomedae*: the Chilean seabass (*Dissostichus eleginoides*) (Yany & Moreno, 1975; Flores & Rojas, 1987), the big-eyed flounder (*Hippoglossina macrops*) (Yany & Moreno, 1975), the Chilean grenadier (*Coelorynchus chilensis*), the trident grenadier (*Coryphaenoides delsolari*), and grey grenadier (*Trachyrhynchus villagai*) (Henríquez *et al.*, 1981).

The size of physical maturity of *H. diomedae* in Chile is reached between 30.0 and 32.5 mm CL in males and 36.5 and 38.0 mm CL in females (Noziglia & Arana, 1976; Arana *et al.*, 2003b). Males should reach maturity in the second year and females in the third year (Noziglia & Arana, 1976). Females grow faster ( $b=2.304$ ) than males ( $b=1.994$ ), which means that females are heavier than males for a given size (Arana & Cristi, 1971).

Both sexes show polymodal size frequency distributions, males with the most significant mode between 25 and 35 mm CL and females between 30 and 50 mm CL (Arana *et al.*, 2003b). The sexual proportion of the species reveals a clear female predominance in the catches (60%); small size-classes (<25 mm CL) are dominated (60-100%) by males, while in the larger size groups females comprise more than 80% (Gaete & Arana, 1986; Arana *et al.*, 2003b).

**IV.3.2. Fishing gear.** The nets used in the *H. diomedae* fisheries are similar to those previously described for the nylon shrimp (*Heterocarpus reedi*) fisheries.

**Table 3.** Main operational variables of the direct assessment cruises for nylon shrimp (*Heterocarpus reedi*) in Chile (1998-2006).  
**Table 3.** Principales variables operacionales en los cruceros de evaluación directa de camarón naílon (*Heterocarpus reedi*) en Chile (1998-2006).

Year	Institution	Ship	Haul	Period	Catch (ton)	Area (km <sup>2</sup> )	Biomass (ton)	Reference
1998	UEDC-UCN	PAM: Antares, Linda Kay	282	Ago - Dic	5	9.547	9.402	Roa <i>et al.</i> (1999)
1999	UCN	PAM: Eicomar, Los Vilos II	263	Jul - Sep	5	11.723	20.236	Acuña <i>et al.</i> (2000b)
2000	PUCV-IFOP-UCN	PAM: Cachagua I, Mancora I, Sunnan II, Tiberiades LM: Isabel S	792	Jun - Jul	23	6.088	21.415	ECM (2000b)
2001	UCN-UdeC	PAM: Foche, Nisshin Maru III LM: Pionero	352	Jun - Jul	13	5.898	21.000	Acuña <i>et al.</i> (2002)
2002	PUCV-IFOP	PAM: Crusoe I, Foche, Lennox, Pionero LM: Isabel S	1.169	Ago - Oct	57	5.987	17.014	Arana <i>et al.</i> (2003 a)
2003	PUCV-IFOP	PAM: Crusoe I, Foche LM: Isabel S	493	Ago - Sep	46	3.690	22.375	Arana <i>et al.</i> (2004)
2004	PUCV-IFOP	PAM: Crusoe I, Lonquimay LM: Isabel S	585	Jul - Sep	32	3.189	21.470	Arana <i>et al.</i> (2005)
2005	PUCV-IFOP	PAM: Foche, Lonquimay, Don Stefan	413	Jul - Ago	65	4.173	27.620	Arana <i>et al.</i> (2006)
2006	UCN-IFOP-UdeC	PAM: Foche LM: Oriente	386	Oct - Dic	86	3.740	37.111	Acuña <i>et al.</i> (2007b)
2008	UCN-UdeC	PAM: Foche LM: Isabel S	570	Jun - Dic	n.d.	3.740	28.772	Acuña <i>et al.</i> (2009)

ECM: Escuela de Ciencias del Mar, UDEC: Universidad de Concepción, PUCV: Pontificia Universidad Católica de Valparaíso, UCN: Universidad Católica del Norte, IFOP: Instituto de Fomento Pesquero. PAM: High seas fishing vessel, LM: Motor boat.

**IV.3.3. Fishery statistics and management.** The extraction of the species started in the 1970s as an activity associated to the trawling fishing of *H. reedi*. However, the *H. diomedea* fishery acquired more importance within the demersal crustacean fisheries off central Chile only since 1999 when the trawling fleet started to land volumes of certain commercial importance. Since 2001, the *H. diomedea* fisheries represent an alternative in view of the restrictive measures implemented for other crustacean species commercially exploited off Chile. This allowed a gradual increase of the landings, reaching 705 ton in 2003, the highest annual value for *H. diomedea* so far reported for Chile. Thereafter, catches have decreased, with landings at levels between 90 and 215 ton yr<sup>-1</sup> (Fig. 24).

The latitudinal distribution of the resource may be compared to that of *H. reedi*, although at a higher depth. In Chile, for administrative purposes, red royal shrimp fisheries cover the maritime area between 18°21'S and 43°44'S. However, commercial fisheries of the species are executed principally between 32°S and 36°S as accompanying fauna of the nylon shrimp fisheries; occasionally hauls are carried out to specifically catch *H. diomedea*. Through the analysis of 6,043 hauls of the industrial and artisanal fleet, Párraga *et al.* (2010) were able to document that higher catch rates (37 and 62 kg per trawling hour) were obtained between 33°53'S and 34°41'S at depths exceeding 500 m; trawling was more successful between November and March (53 kg per trawling hour) than between April and October (42 kg per trawling hour).

**IV.3.4. Current status of the resource.** The red royal shrimp fisheries are managed under the “General Access Regime” (Ley General de Pesca y Acuicultura, Chile). Its commercial exploitation is restricted to catches of the trawling fleet dedicated to fish and other benthic crustaceans.

**IV.3.5. Commercialization.** The species shows a fast post-catch deterioration caused by melanosis (blackening). The species undergoes different production processes to be commercialized as raw, cooked and frozen (peeled tails, IQF) products, and deveined or undeveined (stomach). Local markets offer fresh tails.

**IV.3.6. Conclusions.** Fishing performance for the red royal shrimp is lower than those reported for other crustacean species currently exploited in Chilean waters. According to the estimated vulnerable biomass levels (Arana *et al.*, 2002, 2003b), the resource does not allow the development of large-scale extraction

activities; therefore, it is more likely that fishing of *H. diomedea* act as a complementary activity to the exploitation of other resources such as *H. reedi*, *P. monodon* and *C. johni*. Notwithstanding, the red royal shrimp fisheries represent a relevant economic activity and an important alternative if other crustacean fisheries will be closed once the established quotas are achieved or biological or extractive close seasons are put into force.

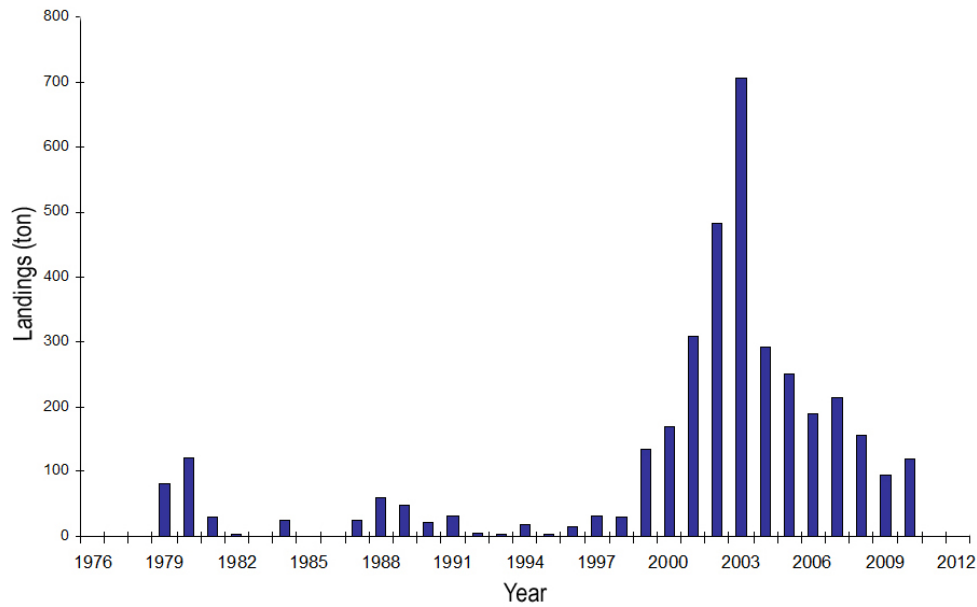
**IV.4. *Campylonotus semistriatus*** Bate, 1888 (Razor shrimp, local name: “camarón navaja”) (Fig. 25). Details concerning the morphological characteristics are provided by Boschi *et al.* (1992) and Retamal & Gorny (2001).

**IV.4.1. Distribution.** The species occurs only in southern South America, and it is present in both the southern Pacific and southern Atlantic (Boschi, 2000). Its geographic distribution in Argentina (Boschi, 2000) covers the area between the San Jorge Gulf (46°S) and Cape Horn (56°S), and in Chile it has been reported from Caldera (27°05'S) to Cape Horn (56°S) (Retamal, 1974, 1994; Henríquez *et al.*, 1981; Arntz *et al.*, 1999; Retamal & Gorny, 2001; Guzmán & Quiroga, 2005; Arana & Ahumada, 2006). It has been suggested that the distribution of this species extends to the north of the Peruvian-Chilean province, and may be even found in southern Peru (Méndez, 1981).

In Argentina, the species occurs between 35 and 545 m (Boschi *et al.*, 1992); in Valparaíso (Chile), *C. semistriatus* has been extracted between 200 and 955 m (Arana & Ahumada, 2006), while its bathymetric distribution in the southernmost area of Chile reaches down to 1,000 m (Leiva *et al.*, 1997).

**IV.4.2. Habitat.** This shrimp is found off the central Chilean coast associated with the Antarctic Intermediate Water mass (AAIW), located between 400-1,000 m of depth. This water mass is characterized by low temperatures (4° to 7°C), along with minimum salinities (>34.4), high oxygen content (>2.5 mL L<sup>-1</sup>) and relative low in nutrient contents (Arana *et al.*, 1976). The razor shrimp inhabits mainly muddy sand bottoms (Arana *et al.*, 1976).

**IV.4.3. Life history parameters.** In general, our knowledge about life history features of representatives of the Campylonotidae is limited. They seem to have a short larval development, undergoing at least two zoeal stages and a decapodid stage (Thatje *et al.*, 2001). Descriptions of the first larval stages and a key for their identification have been provided by Thatje *et al.* (2001).



**Figure 24.** Annual landings of the red royal shrimp (*Haliporoides diomedea*) in Chile. Source of information: SERNAPESCA.

**Figura 24.** Desembarques anuales de la gamba (*Haliporoides diomedea*) en Chile. Fuente de información: SERNAPESCA



**Figure 25.** The razor shrimp *Campylonotus semistriatus*.

**Figura 25.** Camarón navaja *Campylonotus semistriatus*.

In Argentinean waters, *C. semistriatus* is the largest species among the three congeneric species (*C. vagans*, *C. capensis*, *C. semistriatus*) found in the southern Atlantic, with sizes between 17.0 and 35.5 mm CL (Torti & Boschi, 1973). In commercial hauls carried out off central Chile, the size of *C. semistriatus* varied between 11 and 37 mm CL; mean lengths in males was 19.8 mm and 25.9 mm CL in females, indicating a clear size difference between sexes (Arana *et al.*, 2002, 2003b). Arana & Ahumada (2006) emphasized the possible existence of a relationship between the mean size of individuals and the depth of catch, meaning that size increases with depth, so that the largest mean sizes can be found between 700 and 800 m.

Females are more abundant than males (male-female proportion of 1:2.3) in the catches (Arana & Ahumada, 2006). Small individuals are generally males, while females are predominant in specimens > 25 mm CL; the sex ratio is 1:1 in individuals measuring around 21 mm CL (Arana & Ahumada, 2006). These size and sex patterns have led to the conclusion of a possible consecutive protandric hermaphroditism in the species (Torti & Boschi, 1973) from Argentinean waters, with intersex individuals between 22.3 and 25.5 mm CL. This trait, however, is yet to be confirmed for *C. semistriatus* inhabiting Chilean waters.

Females reach sexual maturity between 21.1 and 23.4 mm CL (Arana *et al.*, 2003b). The parameters of the size-weight relationship indicate a negative allometric growth for this shrimp with b values between 2.57 and 2.66 for males and 2.59 and 2.67 for females (Arana & Ahumada, 2006).

**IV.4.4. Fishing gear.** The nets used in the *C. semistriatus* fisheries are similar to those already described for the nylon shrimp (*H. reedi*) and the red royal shrimp (*H. diomedea*) fisheries.

**IV.4.5. Fishery history.** Since this shrimp lives below the depth range where the industrial fleet operates, the available information about this resource corresponds mainly to the results obtained from exploratory or stock assessment studies (Arana *et al.*, 2002, 2003b;

Arana & Ahumada, 2006). Currently, *C. semistriatus* is extracted as part of the by-catch of the nylon shrimp fishery operating in the deepest distribution stratum of *H. reedi* or, more commonly, associated with the *H. diomedea* fishery, carried out in depth ranges similar to those established for the razor shrimp.

Yields obtained for *C. semistriatus* range from 2 to 3 kg per trawling hour (Arana *et al.*, 2003b, 2003c), and its density varies between 0.1 and 804.3 kg km<sup>-2</sup>, with a global mean close to 150 kg km<sup>-2</sup> (Arana & Ahumada, 2006).

**IV.4.6. Current status of the resource.** The resource is only caught as bycatch of *H. reedi* and *H. diomedea* fisheries with only a few ton per year. Currently, its exploitation is not regulated nor subordinated to any extraction regime.

**IV.4.7. Commercialization.** *Campylonotus semistriatus* is used for different production processes, and are commercialized as frozen (peeled-tails, IQF) and fresh-chilled products.

**IV.4.8. Conclusions.** The offshore waters of northern and central Chile have been for several decades the area of an active crustacean fishery carried out by the commercial trawling fleet. These fisheries are mainly targeting the nylon shrimp (*H. reedi*), the yellow squat lobster (*Cervimunida johni*), and the red squat lobster (*Pleuroncodes monodon*), representing the raw material for high added-value products. Due to the reduction of the fishing quotas in the aforementioned species, despite its relatively low abundance and the great depth where the larger individuals occur, the razor shrimp (*C. semistriatus*) may become a resource to be extracted as a complementary species to the previously mentioned species (Arana & Ahumada, 2006).

**IV.5. General conclusions.** The pandalid *H. reedi* is the main shrimp species exploited in Chilean waters, and has supported a relevant fishery due to its available biomass. This scenario has promoted the development of significant fishing activities, which involve an important industrial fleet exploiting this resource. Moreover, the nylon shrimp fishery maintains several companies dedicated to the processing and commercialization of these products for the international markets, which, in turn, generated numerous employment opportunities.

The historical fluctuations observed in *H. reedi* landings require especial attention when implementing management measures; the resource needs to be monitored periodically in order to analyze its

condition, to assess accordingly annual global catch quotas and to promote administrative measures to facilitate a sustainable exploitation of this shrimp.

In the case of the red royal shrimp (*H. diomedea*) and the razor shrimp (*C. semistriatus*), assessments (Arana *et al.*, 2003b; Arana & Ahumada, 2006) have shown considerably lower biomasses compared to those reported for the nylon shrimp (*H. reedi*); moreover, the distribution of these species seems to be patchy and confined to few specific areas. Consequently, the exploitation of these (by-catch) species must be carefully observed to avoid overfishing and to permit a sustainable use of these deep-water shrimp resources.

## V. BRAZIL

### V.1. Introduction and presentation of the species

Marine shrimp fisheries in Brazil have been traditionally targeted to coastal penaeoids (*i.e.* *Farfantepenaeus subtilis*, *F. paulensis*, *F. brasiliensis*, *Litopenaeus schmitti*, *Xiphopenaeus kroyeri*, *Artemesia longinaris*, *Pleoticus muelleri*) distributed both on continental shelf bottoms and estuaries (D'Incao *et al.*, 2002; Aragão *et al.*, 2005; Carvalho, 2005).

Essentially artisanal in its beginning, the activity rapidly diversified from mid 1960's to early 1970's, as a response to government efforts to develop industrial fleets and facilities in Brazil. While well succeeded in adding a new scale to the national shrimp fisheries, building up an excessive fishing capacity coupled with management weakness lead to an overexploitation of most Brazilian shrimp stocks in a few years (Valentini & Pezzuto, 2006).

This scenario remained quite unchanged up to late 1990's, when local industrial trawler fleets expanded their operations to deeper areas of the Exclusive Economic Zone (EEZ), in search of new and profitable resources which could compensate economic losses faced in the traditional coastal fishing grounds (Perez *et al.*, 2001). Concurrently, a new governmental policy trying to develop deep-water fisheries in Brazil has started, inaugurating a new chapter in its fishery history. This policy was based upon implementing a program of specialized foreign vessels chartered by national companies, which lasted for nearly 11 years. Both processes, mediated by learning and technological adaptations of the local fleets, have resulted in the establishment of new foreign and domestic fisheries, including bottom gillnetting for the monkfish (*Lophius gastrophisus*), trawling for Argentine hake (*Merluccius hubbsi*), Brazilian codling (*Urophycis mystacea*) and Argentine

squid (*Illex argentinus*) and potting for geryonid crabs (*Chaceon spp.*) (see review in Perez *et al.*, 2009a).

After some individuals had been caught incidentally in the year 2000, a deep-water shrimp fishery also emerged in 2003, when two foreign vessels started to target three valuable species pertaining to the family Aristeidae (see Pezzuto *et al.*, 2006): the scarlet shrimp (locally called “carabinero”), *Aristaeopsis edwardsiana* (Johnson, 1867) (Fig. 2); the giant red shrimp (locally called “moruno”), *Aristaeomorpha foliacea* (Risso, 1827) (Fig. 1), and the purplehead gamba prawn (locally called “alistado” shrimp) *Aristeus antillensis* A. Milne Edwards & Bouvier, 1909 (Fig. 4). A brief summary about the distribution and ecology of these three species can be found in the present review, in the chapter about Mexico. This episode inaugurated a new Aristeidae fishery in Latin America. However, “carabinero” and “alistado” shrimps have long been seasonally exploited in French Guiana by local penaeid trawlers (Guéguen, 1998), while the “moruno” shrimp is known to sustain several well-established fisheries in Mediterranean waters (Sardà, 2000).

Since its recent development in Brazil, deep-water shrimp fishery and biology has been the focus of different publications, including Araújo-Silva *et al.* (2002a, 2002b), Asano Filho & Holanda (2005), Costa *et al.* (2005), Pezzuto *et al.* (2006), Pezzuto & Dias (2007), Serejo *et al.* (2007), Tavares & Serejo (2007), Dallagnolo (2008), Dias (2009), Dallagnolo *et al.* (2009a; 2009b), Perez *et al.* (2009a, 2009b) and Pezzuto & Dias (2009). These were based either on scientific surveys, or biological and fishing data collected aboard foreign commercial vessels, as 100% of their trips were mandatorily monitored by observers and Satellite Tracking systems.

**V.2. Fishing fleets.** The fishery developed along most of the Brazilian EEZ; however, the fishing activities were concentrated in 11 slope-fishing grounds situated between Espírito Santo (18°S) and Rio Grande do Sul (32°S) states (Fig. 26). Catches were obtained from a very narrow bathymetric stratum between 700 and 750 m depth (Dallagnolo *et al.*, 2009a); this situation imposed severe technological constraints to the domestic trawlers accustomed to operate in areas shallower than 500 m at most.

Consequently, deep-water shrimp fishery in Brazil was dominated by eight foreign stern trawlers, chartered by national companies, and an additional nationalized vessel with similar characteristics. Most of them between 30 and 40 m length, powered by approximately 1,000 HP engines, both equipped with processing facilities and freezing chambers (Fig. 27).

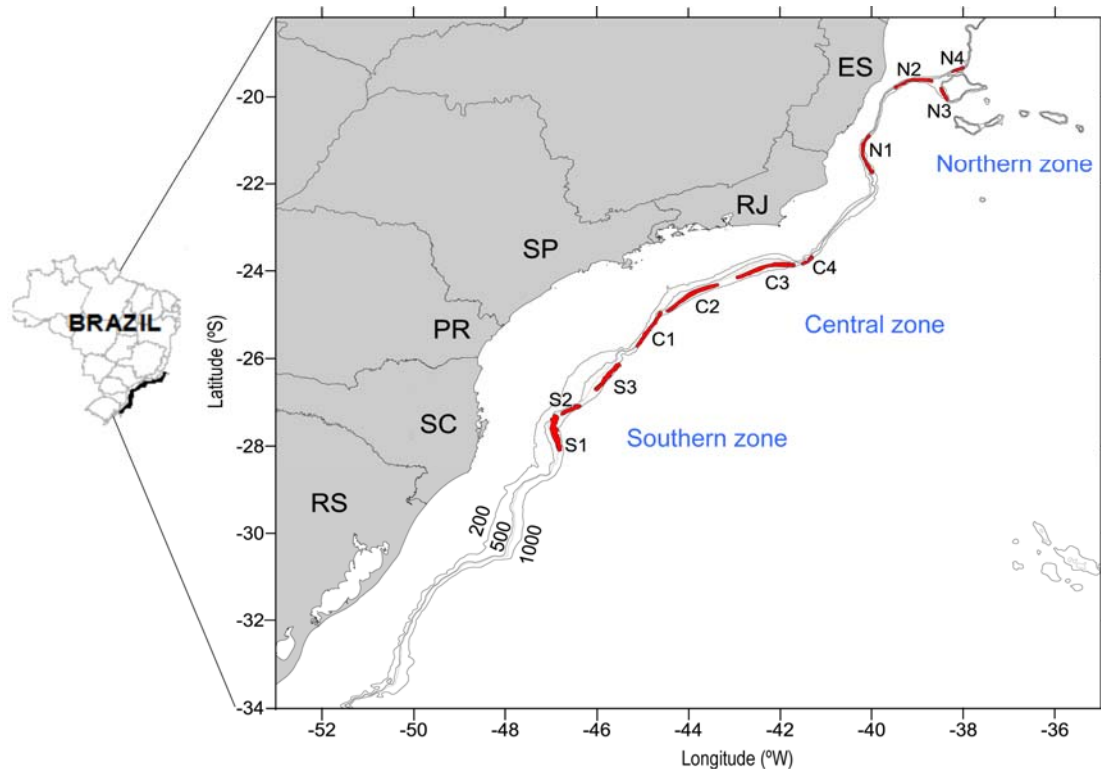
These trawlers were capable to perform fishing trips lasting over one month. A variety of bottom trawl nets were employed by the fleet, which differed mostly in head rope length (45 to 95 m) and mesh size (40 to 80 mm). Trawling velocity ranged between 2 and 3 knots, and towing lasted on average 4 h. Each trawl swept a linear extension of approximately 21 km (maximum 73 km) (Dallagnolo, 2008; Dallagnolo *et al.*, 2009a).

**V.3. Statistics.** From 2002 to 2009, production of deep-water shrimps in Brazil summed a total of 719 ton (fresh weight). *Aristaeopsis edwardsiana* constituted the dominant species in the catches, accounting for 75.4% of the landings between 2002-2009. Catches of this species increased steadily from 13.0 ton in 2002 to 182.6 ton in 2005, declining to only 13.7 ton in 2009 (Table 4). While generally playing a secondary role in the fishery (20.6% of the total), *Aristaeomorpha foliacea* dominated in the fishing grounds N1 and C4 (Fig. 26), surpassing the production of *A. edwardsiana* (Dallagnolo *et al.*, 2009a). Landings of this species increased continuously up to 2006, when a maximum of 51.7 ton was attained. *Aristeus antillensis* accounted only for 3% of the deep-water landings in Brazil. Its production increased from 0.3 ton in 2002 to 15.8 ton in 2005, but declined in the subsequent years (Table 1). Profitable catches of this species were obtained only in two small fishing grounds situated at nearly 19.5°S (Pezzuto & Dias, 2009).

As compared to the other species, *A. edwardsiana* produced the highest mean annual catch rates (4.7 to 14 kg h<sup>-1</sup>). However, they revealed a declining pattern in time, reducing between 26% and 61% depending on the fishing area. On the other hand, and in spite of being generally lower (0.76 to 6.3 kg h<sup>-1</sup>), mean catch rates of *A. foliacea* increased substantially at rates varying between 327% and 835%. Based on biological data published by Pezzuto & Dias (2007), Dallagnolo *et al.* (2009a) hypothesized that the inversion of the mean catch rates in *A. edwardsiana* and *A. foliacea* may be related to their different life strategies: the former species is larger and mature later in life, while the latter is smaller and presumably faster-growing. This difference may confer an advantage to *A. foliacea* in expanding its distribution and abundance after the massive removal of *A. edwardsiana* from the fishing grounds.

*Aristaeus antillensis* produced the lowest catch rates among the Brazilian deep-water shrimps (0.005 to 2.4 kg h<sup>-1</sup>), which decreased by 65% between 2004 and 2007 (Dallagnolo *et al.*, 2009a). Such changes in commercial catch rates were confirmed by biomass assessments (Dallagnolo, 2008). As a conse-





**Figure 26.** Main deep-water shrimp fishing grounds in southern Brazil as identified by Dallagnolo *et al.* (2009a). ES, RJ, SP, PR, SC, RS correspond to the states of Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul, respectively.

**Figura 26.** Principales caladeros de pesca de camarones de aguas profundas frente a la costa sur de Brasil, identificadas por Dallagnolo *et al.* (2009a). ES, RJ, SP, PR, SC, RS corresponde a los estados brasileiros de Espírito Santo, Rio de Janeiro, São Paulo, Paraná, Santa Catarina y Rio Grande do Sul, respectivamente.



**Figure 27.** A typical deep-water shrimp trawler that operated in Brazil between 2003 and 2009.

**Figura 27.** Buque arrastrero típico utilizado en Brasil para la pesca de camarones de aguas profundas entre 2003 y 2009.

quence of declining yields and associated problems with the commercial viability, the fishery for the three species stopped in 2009. The production was entirely exported to European markets.

**V.4. Management.** A management plan for this fishery was developed, discussed and approved under the Consultant Committee for the Management of Deep-water Resources (Ministry of Fisheries and Aquaculture of Brazil) (Dallagnolo *et al.*, 2009b). However, this plan was never implemented due to unclear reasons (see details of the Brazilian fishery institutional framework in Perez *et al.*, 2009a). The plan included: limits to the fleet size (two vessels); fishing area ( $18^{\circ}20'S$  to  $28^{\circ}30'S$ , 500-1000 m depth); a global total allowable catch (TAC) for the three species together ( $60 \text{ ton year}^{-1}$ ); gear restrictions (stern trawl method, minimum cod-end mesh size 60 mm stretched); by-catch limits (*Chaceon* spp. 15% and *L. gastrophysus* 5% of the total catch); exclusion areas (a quadrant between Rio de Janeiro and São Paulo

**Table 4.** Landing statistics of the deep-water shrimps in Brazil, between 2002 and 2009. All values in kg.

**Tabla 4.** Desembarque de camarones de aguas profundas en Brasil, entre 2002 y 2009. Todos los valores están expresados en kg.

Year	Species			Total
	<i>Aristaeopsis edwardsiana</i>	<i>Aristaeomorpha foliacea</i>	<i>Aristaeus antillensis</i>	
2002	13.021	-	-	13.021
2003	58.928	4.585	475	63.988
2004	81.585	14.861	5.489	101.935
2005	182.633	42.568	15.828	241.029
2006	99.325	51.756	5.365	156.446
2007	40.231	8.896	774	49.901
2008	53.021	21.604	434	75.059
2009	13.703	3.831	172	17.706
Total	542.447	148.101	28.537	719.085

Source of information: Grupo de Estudos Pesqueiros (Universidade do Vale do Itajaí)

States, seamounts, coral bottoms and areas “N” of 21°S when catches of *A. antillensis* attain 4.4 ton); rotation of harvestable areas (“N” and “S” from the main exclusion quadrant); and control measures as logbooks, satellite tracking and observers in all trips.

**V.5. Conclusions.** The commercial exploitation of aristeid shrimp resources in Brazil developed as a typical “gold rush” fishery. The production peaked only four years after the start of directed foreign fleet operations and stopped four years later. In spite of the governmental decision to implement a mandatory and detailed observer program, coupled with scientific efforts, aiming at obtaining and processing timely information about the species, management measures were not enforced throughout the period. Overexploitation of the most abundant and valuable species (*A. edwardsiana*) was perceived in a few years (Dallagnolo, 2008). As a consequence, and even considering the concurrent increase in catch rates and yields of *A. foliacea*, this fishery turned economically unprofitable and was abandoned.

Contrary to the domestic gillnetting for monkfish and trawling for Argentine hake, Brazilian codling and Argentine squid fisheries in depths <500 m, which were made possible by minor modifications of existing vessels, technological and operational limitations impeded the development of a national fishery for aristeid shrimps in deeper areas of the Brazilian slope. While such restrictions would have contributed to alleviate the fishing pressure over the deep-water shrimp stocks, during the last years, governmental resistance to implement the respective

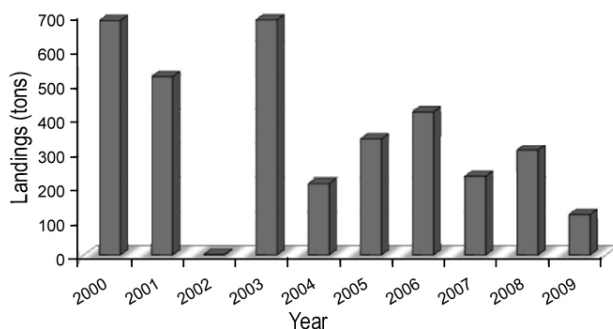
management plan has placed the resource under potential risk.

## VI. OTHER COUNTRIES

Deep-water shrimps are commercially exploited along the Pacific coast of Colombia. The term “deep-water” in Colombian fisheries refers to depths below 72 m (Puentes *et al.*, 2007) or below 36 m (INVEMAR, 2009). According to INVEMAR (2009), commercially exploited deep-water shrimps include *Solenocera agassizii* as well as *Farfantepenaeus brevirstris* and *F. californiensis* (in the present review, we do not consider these two penaeid shrimps as deep-water species). Puentes *et al.* (2007) mentioned additionally *Heterocarpus* spp. (according to the authors *H. vicarius* and/or *H. hostilis*); however, these pandalid shrimps are not the target species and are obtained as by-catch associated to the fishery of the above-mentioned three shrimp species. Puentes *et al.* (1994) and Rueda *et al.* (2004) provided a description of the shrimp trawler fleet operating in Pacific Colombia. In 1993, the deep-water shrimp trawler fleet consisted of 23 boats, while in 2003 17 boats were used exclusively to extract deep-water shrimps, and an additional seven trawlers were allowed to fish in both shallow- and deep-water grounds. The trawlers used for the deep-water shrimp fisheries have a length varying between 15.0 and 24.4 m, and most of them measure between 20-22 m (Rueda *et al.*, 2004). Landings of the three above-mentioned deep-water shrimps varied between roughly 575 ton (1993) and 1240 ton (2000 and 2006); the most recent data (2008) indicate landings of 753 ton, comprised mainly (55.2%) of *S.*

*agassizii* (INVEMAR, 2009). In the specific case of *S. agassizii*, reported landings peaked in 2003 with approximately 688 ton (Fig. 28); since 2006, catches tend to continuously decrease, reaching 118 ton in 2009 (Barreto *et al.*, 2010). As mentioned by Barreto & Bordo (2008), 69% of the fished population of *S. agassizii* consists of immature individuals; these authors characterize this deep-water resource as fully exploited. The study of Puentes *et al.* (2007) revealed the presence of 54 fish species belonging to 35 families, 11 crustacean species within 11 families, and one mollusk species, as by-catch of the deep-water shrimp fishery in Colombia; all crustaceans, including species of potential commercial importance (*Heterocarpus* spp. and *Pleuroncodes monodon*) are considered as discards. Several authors (Pedraza *et al.*, 2002; Rubio *et al.*, 2005) indicated that a trap fishery for *H. hostilis* exists, operating between 600 and 900 m depth. As far as we know, no official statistics about this trap fishery are available, and this fishery has been abandoned (V. Puentes, Ministerio de Ambiente, Vivienda y Desarrollo Territorial Colombia, *pers. comm.*) The incorporation of turtle excluder devices (TED), a fishing ban between January and February, and global catch quota ((for 2008: 930 ton for the three above-mentioned deep-water shrimp species (Barreto & Borda, 2008)) are the management strategies implemented by the Colombian authorities (Ruedo *et al.*, 2004; Barreto & Borda, 2008; Barreto *et al.*, 2010; Campo-Soto, 2010).

Two species have been the target of a traditional deep-water shrimp fishery in French Guiana (western central Atlantic): *Solenocera acuminata* Pérez-Farfante & Bullis, 1973 and *A. edwardsiana*. This fishery started in 1988; *S. acuminata* was fished at night at depths of about 200 m, while the second



**Figure 28.** Annual landings (2000-2009) of *Solenocera agassizii* in Colombia. Source of information: Barreto *et al.* (2010).

**Figura 28.** Desembarques anuales (2000-2009) de *Solenocera agassizii* en Colombia. Fuente de información: Barreto *et al.* (2010).

species occurred predominantly at a depth between 600 and 700 m (Guéguen, 1998). Statistics concerning the annual catches of *A. edwardsiana* are available only until 1993 (see Guéguen, 1998): reported landings started in 1988 with 93 ton, decreased continuously to 34 ton in 1990, and reached its highest value in 1991 with 258 ton; thereafter, landings decreased again to 140 ton in 1993. According to Guéguen (1998), the CPUE of this fishery fluctuated between 0.341 ton h<sup>-1</sup> (1988) and 0.175 ton h<sup>-1</sup> (1990). It remains unclear whether this deep-water shrimp fishery in French Guiana is still active or has been abandoned.

## VII. CONCLUSIONS AND RECOMMENDATIONS

Commercial deep-water fisheries are currently carried out in Chile, Colombia, and Costa Rica. Our compilation revealed the presence of a total of 17 deep-water shrimp species with different levels of potential for a commercial exploitation from Latin American offshore waters, including ten penaeoid and seven caridean species (Table 5). Currently, four species (*Haliporoides diomedae*, *Solenocera agassizii*, *Heterocarpus affinis*, *H. reedi* and *H. vicarius*) are the target of a commercial fishery, and three other species (*Aristaeomorpha foliacea*, *Aristaeopsis edwardsiana*, and *Aristeus antillensis*) have been commercially exploited in Brazil, but these fisheries are now closed. *Aristaeopsis edwardsiana* have been reported also to support a seasonal fishery in French Guiana since 1988, but there are no data available about the current status of this fishery (Guéguen, 1998). While *S. agassizii* and *H. vicarius* are fished in Costa Rica and Colombia, the three aristeid species have been reported from both Brazil and Mexico, but they were exploited exclusively in Brazil.

To the best of our knowledge, an implemented management plan for the exploitation of deep-water shrimps only exists in Chile. However, in Colombia fishing closure (January and February) and annual catch quota were put into force to protect the deep-water shrimp resource (Barreto & Borda, 2008; Barreto *et al.*, 2010; Campo Soto, 2010). In Brazil, detailed fishery regulations for the aristeid fishery were approved but never implemented. As a consequence, the main target-species (*A. edwardsiana*) became rapidly overexploited, and the fisheries have been abandoned. In the remaining countries studied in the present review, there are no special management strategies directed towards the sustainability of these valuable deep-water resources.

**Table 5.** General information and current fishery status of the main deep-water shrimp species around Latin America. “Geographic distribution” indicates the known geographic distribution of the species in Latin America, and “Country” refers to the country where a commercial fishery exists or not; the term “unknown” means that it is unclear if this fishery is still active. References concerning bathymetric and geographic distribution of the species are mentioned in the text; otherwise they are indicated at the end of the table.

**Tabla 5.** Información general y situación de las principales especies de camarones alrededor de América Latina. La “Distribución geográfica” indica el área conocida en que se distribuye la especie en América Latina, y “País” se refiere al país donde se desarrolla o no la pesquería comercial; el término “desconocido” significa que no está claro si la pesquería es todavía activa. La referencia respecto a la batimetría y distribución geográfica de las especies está mencionada en el texto; en caso contrario, está señalada al final de la tabla.

Infraorden	Family	Species	Depth range (m)	Geographic distribution	Country	Commercial fishery
Penaeoidea	Aristeidae	<i>Aristaeomorpha foliacea</i>	250 - 1300	Gulf of Mexico, and in the Caribbean Sea to Brazil	Mexico Brazil	no no longer
		<i>Aristaeopsis edwardsiana</i>	274 - 1850	Grand Bank south to Brazil including the Gulf of Mexico and Caribbean Sea	Mexico Brazil French Guiana	no no longer unknown
		<i>Aristeus antilleanis</i>	200 - 1144	Florida to Brazil, including the Gulf of Mexico and the Caribbean Sea	Mexico Brazil	no no longer
	Benthescymidae	<i>Benthescymus tanneri</i>	600 - 1500	Gulf of California, Panama, Colombia, Galapagos Islands, Ecuador and Peru	Peru	no
	Penaeidae	<i>Parapenaeus americanus</i>	190 - 412	Gulf of Mexico to Uruguay	Mexico	no
		<i>Penaeopsis serrata</i>	120 - 640	Amphi-Atlantic distribution	Mexico	no
		<i>Haliporoides diomedae</i>	240 - 1865 <sup>1</sup>	Gulf of Panama to Chiloe Island in Chile	Chile Peru	yes no
		<i>Pleuoticus robustus</i>	180 - 730	Gulf of Mexico and the Caribbean Sea to French Guiana	Mexico	no
	Solenoceridae	<i>Solenocera acuminata</i>	31 - 622 <sup>2</sup>	Caribbean Sea, British Honduras to Venezuela; Gulf of Paria to French Guiana <sup>2</sup>	French Guiana	unknown
		<i>Solenocera agassizii</i>	16 - 350	Nicaragua to Peru	Costa Rica Colombia	yes yes
Campylonotidae	<i>Campylonotus semistriatus</i>	35 - 1000	Argentina, Chile, Peru	Chile	yes	
Caridea	Nematocarcinidae	<i>Nematocarcinus agassizii</i>	190 - 1860 <sup>3</sup>	Sinaloa, Mexico, to Peru, Cocos, Malpelo and Galapagos Islands <sup>4</sup>	Peru	no
		<i>Heterocarpus affinis</i>	760 - 1240	Gulf of California (Mexico) to Peru	Costa Rica	yes
	<i>Heterocarpus hostilis</i>	695 - 800	Gulf of Panama to Isla del Coco in Peru	Peru Colombia	no unknown	
	<i>Heterocarpus reedi</i>	155 - 800	central-northern to central-southern Chile, Peru	Chile	yes	
	<i>Heterocarpus vicarius</i>	73 - 1454	Gulf of California (Mexico) to Peru	Costa Rica Colombia Peru	yes unknown no	
Pasiphaeidae	<i>Pasiphaea magna</i>	509 - 1019 <sup>5</sup>	From Oregon (USA) to Panama, Peru and Chile <sup>5</sup>	Peru	no	

References: <sup>1</sup>Hendrickx (1995); <sup>2</sup>Pérez Farfante & Bullis (1973); <sup>3</sup>Burukovsky (2001); <sup>4</sup>Wicksten & Hendrickx (2003); <sup>5</sup>Wehrmann & Carvacho (1997)

Probably as a consequence of the lack of appropriate fishery regulations, the deep-water fishery in Costa Rica is about to collapse, despite the fact that different stakeholders requested twice a temporary closure of selected deep-water species (see Wehrmann & Nielsen-Muñoz, 2009). However, even if management plans would be implemented, the lack of efficient control mechanisms seems to be a typical problem in developing countries. Nevertheless, national fishery agencies have the responsibility to protect their marine resources and need to implement measures to avoid the ongoing deterioration of many Latin American deep-water shrimp resources.

The lack of adequate information about the biology of these deep-water shrimps represents an important impediment to the development of management strategies oriented towards the sustainability of these vulnerable resources (Bensch *et al.*, 2008; Polidoro *et al.*, 2008). Considering this situation, it becomes evident that more communication and collaboration between the different stakeholders in the Latin American region is needed. As a first step, it is recommendable the identification of the governmental and non-governmental institutions associated with and interested in the use of deep-water resources, in order to establish a Latin American network. It seems as well advisable to include interested parties from the Mediterranean region and other countries or regions, given their exhaustive experience with the biology of deep-water shrimps, including some of the same species as found in Latin America (*e.g.* Sardà *et al.*, 2003, 2004; Politou *et al.*, 2005). Such network building will facilitate the knowledge transfer between different countries and institutions. Another measure should be the creation of a website to compile available information about these deep-water resources. On a national level, it is suggested to digitize the so-called “grey literature”. There is no question that many reports and thesis’ containing valuable data about deep-water shrimps are stored somewhere, practically without public access. Therefore, and following the example of the Census of Marine Life project COMARGE (Continental Margins and Ecosystems) concerning squat lobsters (see <http://decapoda.nhm.org/references/squatlobsters.htm>), scanning these documents and putting them on a website open to the public would be an important step to create an updated database. Such a searchable and constantly updated database will represent a valuable source of information for researchers and decision makers. Moreover, it will allow detecting gaps in the knowledge about these resources, and that should lead to the development of regional research plans aimed towards supporting measurements for a sustainable use of deep-water shrimps in Latin America.

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