Latin American Journal of Aquatic Research
E-ISSN: 0718-560X
lajar@ucv.cl
Pontificia Universidad Católica de Valparaíso
Chile

Dallagnolo, Rodrigo; Alvarez Perez, José Angel; Pezzuto, Paulo Ricardo; Wahrlich, Roberto
The deep-sea shrimp fishery off Brazil (Decapoda: Aristeidae): development and present status
Latin American Journal of Aquatic Research, vol. 37, núm. 3, 2009, pp. 327-345
Pontificia Universidad Católica de Valparaíso
Valparaiso, Chile

Lat. Am. J. Aquat. Res., 37(3): 327-346, 2009
"Deep-sea fisheries off Latin America"
P. Arana, J.A.A. Perez & P.R. Pezzuto (eds.)
DOI: 10.3856/vol37-issue3-fulltext-5

Research Article

The deep-sea shrimp fishery off Brazil (Decapoda: Aristeidae): development and present status

Rodrigo Dallagnolo[1], José Angel Alvarez Perez[1], Paulo Ricardo Pezzuto[1] & Roberto Wahrlich[1]
[1]Universidade do Vale do Itajaí, Centro de Ciências Tecnológicas da Terra e do Mar
Rua Uruguai 458, CEP 88.302-202, Itajaí, SC, Brazil

ABSTRACT. The development of a deep-sea fishery for aristeid shrimps off Brazil is reviewed from its early days in 2002. Descriptive data were collected by observers on board 75 directed fishing trips conducted in the study period, with a total of over 15,000 monitored trawls. An incipient fishing phase took place between November 2000 and October 2002, when aristeid shrimps were occasionally reported in the bycatch of operations mostly targeting the Argentine hake (*Merluccius hubbsi*). After that, a directed fishery was established for these resources. All nine vessels involved in this fishery (one national and eight chartered) concentrated on 11 limited grounds between 700 and 800 m deep and 18ºS and 34ºS. The main species caught between November 2002 and May 2007 was the "carabinero" *Aristaeopsis edwardsiana* (456,710 kg), followed by the "moruno" *Aristaeomorpha foliacea* (121,497 kg), and then the "alistado" *Aristeus antillensis* (27,919 kg). The trawlers operate in conjunction, such that the total area of each fishing ground was swept at least twice. This harvest pattern substantially reduced "carabinero" catch rates from 14 kg hour^{-1} in the first sampled trimester to 4 kg hour^{-1} in the last. Despite the inferred biomass reduction of this species, the fishery has continued without a formal management plan.

Keywords: trawl fishery, deep-water shrimps, Aristeidae, Brazil.

La pesquería de gambas de profundidad en Brasil (Decapoda: Aristeidae): desarrollo y estado actual

RESUMEN. Se revisa el desarrollo de una pesquería en aguas profundas dirigida a gambas aristeideas en Brasil. Desde su inicio, en 2002, los datos descriptivos fueron obtenidos por observadores a bordo de 75 viajes de pesca realizadas en ese período que resultaron en más de 15.000 arrastres monitoreados. Una fase incipiente de la pesquería se estableció entre noviembre de 2000 y octubre de 2002, cuando gambas aristeideas fueron registradas en la captura accidental de operaciones de pesca dirigidas principalmente a la merluza-argentina (*Merluccius hubbsi*). A ésta sobrevino una fase dirigida en que participaron nueve arrastreros (uno nacional y ocho arrendados). Estos buques concentraron sus operaciones en 11 fondos de pesca angostos entre 700 y 800 m de profundidad y los paralelos 18ºS y 34ºS. Las principales especies capturadas entre noviembre de 2002 y mayo de 2007 fueron el "carabinero" *Aristaeopsis edwardsiana* (456,710 kg), seguido del "moruno" *Aristaeomorpha foliacea* (121,497 kg), y el "alistado" *Aristeus antillensis* (27,919 kg). Los arrastreros operaran de forma agregada y esto hace que el área total de cada zona de pesca haya sido arrastrada al menos dos veces. Este patrón de explotación ha producido reducciones substanciales en las tasas de captura del "carabinero" que varió de 14 kg hora^{-1} en el primer trimestre de monitoreo a 4 kg hora^{-1} en el último. A pesar de la aparente reducción de biomasa de esta especie, la pesquería ha continuado sin un plan formal de manejo.

Palabras clave: pesca de arrastre, gambas de aguas profundas, Aristeidae, Brasil.

Corresponding author: Rodrigo Dallagnolo (rdallagnolo@univali.br)

INTRODUCTION

The recent development of deep-water fisheries off Brazil has been strongly influenced by a foreign vessel-chartering program implemented by the Brazilian government in 1998. From 2000 onwards, large vessels operating gillnets, longlines, trawls, and traps occupied virtually unexplored areas of the continental slope and established unprecedented fishing regimes on shellfish and finfish species, including deep-sea crabs (*Chaceon notialis* and *C. ramosae*), the argentine shortfin squid (*Illex argentinus*), the monkfish (*Lophius gastrophysus*), the Argentine hake (*Merluccius hubbsi*), and others (Perez *et al*., 2003). Because these chartered operations were intensely monitored by observers and VMS (satellite *vessel monitoring systems*) as part of their legal obligations, a large amount of fishing and biological data was made available and used in the elaboration of preliminary stock assessments and management plans for these resources (Perez *et al*., 2002a, 2002b, 2003, 2005; Wahrlich *et al*., 2004; Perez & Wahrlich, 2005; Pezzuto *et al*., 2006a).

As these slope fisheries intensified, principally off the southeastern and southern sectors of the Brazilian coast, new resources were recorded as bycatch components, most notably, the valuable deep-sea shrimps of the family Aristeidae. In late 2002, as productive concentrations of these resources were identified, a new directed trawl fishery began to develop, the latest and deepest since the onset of the chartering program (Pezzuto *et al*., 2006b; Perez *et al*., 2009a).

This paper reviews the initial five years of the deep-sea shrimp fishery off the Brazilian coast, adding complementary new data on the early development phase (2000-2004) previously described by Perez *et al.* (2009a) and Pezzuto *et al*. (2006b). The study also characterizes the temporal and spatial trends of the fishery through the subsequent, more dynamic period (2004-2007).

MATERIAL AND METHODS

Fishing data were obtained from commercial operations conducted on the continental slope off the southeastern and southern sectors of the Brazilian coast, delimited by the parallels 18ºS and 34ºS and by the 200 to 1000 m isobaths (Fig. 1). This gives a surface area of 250,000 km², averaging 1,600 km in length and 150 km in width and characterized by topographic irregularities including plateaus and submarine canyons (Zembruscki, 1979).

All analyzed data originated from satellite VMS and observers on board all chartered-fleet fishing operations conducted from October 2000 to May 2007. Each trawl conducted by chartered vessels within this period was described by position, date, time, and depth (m) at deployment and retrieval, as well as the trawl speed (knots), trawl duration (h), head rope length (m), mesh size at cod-end (mm), and catch composition (kg). The nationalized trawler was the only one not subjected to the VMS or obligatory observers. Logbooks were the only source of this vessel's catch and effort information, as provided by the vessel skipper for nine fishing trips between 2005 and 2006.

Catch (kg), effort (trawled hour), and catch rate (kg hour^{-1}) variability were summarized by year and trimester, considering the different aristeid shrimp species separately. Spatial patterns of the fishing area occupation, catch, and effort were analyzed through VMS-generated individual positions during the fishing trips as well as geographic trawl positions as recorded by observers. Deployment and retrieval positions for individual trawls conducted by the entire fleet in each year were plotted on a cartographic basis and fishing *sectors* were delimited, following Pezzuto *et al*. (2006b): (a) northern, between 18º20'S and 22ºS; (b) central, between 22ºS and 26ºS; and (c) southern, between 26ºS and the southernmost limit of the Brazilian EEZ (Fig. 1). Fishing sectors were further subdivided into fishing grounds as delimited by the isobaths that enclosed 80% of the fishing trawls. Each fishing ground was referenced by a capital letter N, C, or S, according to the sector (northern, central, or southern) in which it was identified and followed by a number that increased from south to north (*i.e.* C1 was the southernmost fishing ground of the central fishing sector).

The surface areas of fishing sectors and fishing grounds were calculated by transforming latitude and longitude coordinates into UTM and then converting these into metric units. All geometric coordinates were referenced on the basis of Datum SAD 1969 (South American Datum) and their transformations considered three UTM zones that cover southeastern and southern Brazil (UTM 22, UTM 23 and UTM 24).

RESULTS

Trawlers, gear, and trawling operations

A total of sixteen chartered trawlers operated in the Brazilian slope waters since the year 2000. Two of them, "Joana" and "Nuevo Apenino", recorded aristeid shrimps as bycatch components. For another

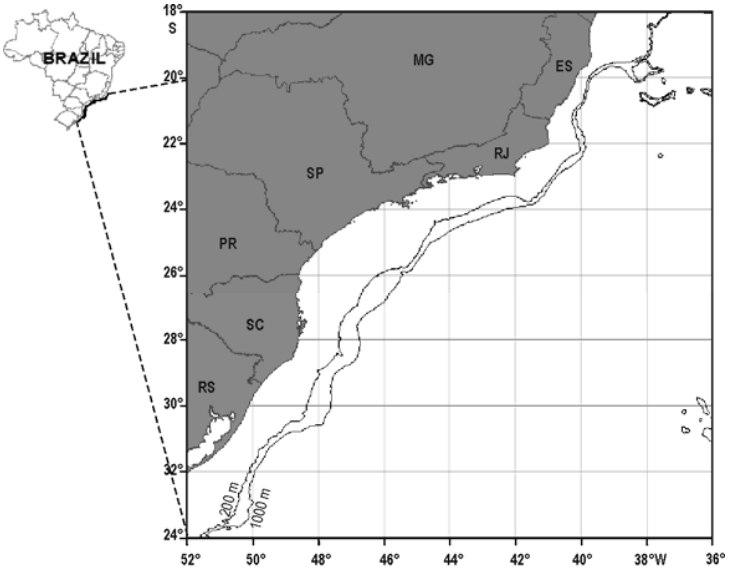

Figure 1. Study area in southeastern and southern Brazil, with an emphasis on the continental slope between 200 m and 1000 m depth and the latitudinal limits of the aristeid shrimp trawling operation sectors. Abbreviations refer to major states in the study area: MG: Minas Gerais, ES: Espírito Santo, RJ: Río de Janeiro, SP: São Paulo, SC: Santa Catarina, RS: Río Grande do Sul, and PR: Paraná.

Figura 1. Área de estudio en el sureste y sur de Brasil con énfasis en el talud continental entre 200 y 1000 m de profundidad y límites latitudinales de los sectores de operación de la pesca de arrastre dirigida a las gambas aristeideas. Las abreviaturas se refieren a los estados en el área de estudio, MG: Minas Gerais, ES: Espírito Santo, RJ: Río de Janeiro, SP: São Paulo, SC: Santa Catarina, RS: Río Grande do Sul y PR: Paraná.

eight trawlers, these shrimps were the main target species. All shrimp trawlers were longer than 30 m, powered by approximately 1,000 HP engines, and capable of performing fishing trips lasting over one month (Table 1).

A variety of trawl nets were employed by these vessels, most of them differing in head rope length, which ranged from 45 to 95 m, and mesh size, which ranged from 40 to 80 mm (Figs. 2a and 2b).

Excluding those fishing operations where deep-sea shrimps were considered to be by-catch, a total of 75 fishing trips, around 15,000 trawls, and over 63,000 trawled hours were focused on aristeid shrimps off southeastern and southern Brazil from 2002 to 2007 (Table 1). Trawl velocity ranged between 2 and 3 knots, although faster (4.0- 4.5 knots) and slower (under 2.0 knots) trawls were also recorded (Fig. 3a). The duration of trawls was normally distributed around a mean value of 4.06 h ($\pm$ 0.007 SE) (Fig. 3b). The product of both variables (trawl velocity and duration) allowed us to estimate that each trawl swept an average linear extension of approximately 21 km, with maximum values of 73 km (Fig. 3c). Wing spread was estimated as approximately half of the head rope length as proposed by Sparre & Venema (1997). This measure, when multiplied by the trawl length values, indicated that each trawl swept a mean surface area of 0.73 km² (Fig. 3d). However, this surface frequently surpassed 1 km² and reached 2.3 km² in extreme cases.

Catch composition

Altogether, these trawlers caught approximately 600 ton of deep-sea shrimps. The "carabinero" shrimp (*Aristaeopsis edwardsiana*) was the most abundant in the catches, followed by the "moruno" shrimp (*Aristaeomorpha foliacea*) and finally the "alistado" shrimp (*Aristeus antillensis*) (Table 2). Catches of all three species increased steadily until 2005, a trend also observed in the total effort as expressed either in number of trawls or trawled hours. In 2006, the fishing effort decreased around 26% (trawled hours) and 24% (number of trawls), coinciding with a 45% and 66% decrease in catches of "carabinero" and "alistado" shrimps and a 21% increase in "moruno" shrimp catches.

Retained and commercialized bycatch were mainly the deep-sea crab *Chaceon* spp. (128,950 kg), the Argentine hake *Merluccius hubbsi* (71,426 kg), the gulf hake *Urophycis cirrata* (25,076 kg), the monkfish *Lophius gastrophysus* (20,305 kg), and the Argentine

Table 1. Technical characteristics of chartered trawlers and fishing operations that reported catches of aristeid shrimps (targeted and non-targeted) off the Brazilian coast from 2000 to 2007. Total number of trips, tows, and trawled hours include only fishing trips conducted during the "targeting phase" (*i.e.* excluding all trips by the vessels "Joana" and "Nuevo Apenino" and fishing trips of the vessels "Mar Maria" and "Costa Grande", which were targeting demersal fishes on the upper slope).

Tabla 1. Características técnicas de los arrastreros arrendados y de las operaciones de pesca con capturas de gambas aristeideas (pescas dirigidas y no dirigidas a estas especies) en la costa de Brasil entre 2000 y 2007. El número total de viajes, arrastres y horas de arrastre incluye solamente operaciones realizadas durante la "fase dirigida" (*i.e.* excluye todas los viajes de los buques "Joana" y "Nuevo Apenino", y los viajes de los buques "Mar María" y "Costa Grande" que fueron dirigidos a peces demersales del talud superior).

Vessel	Origin	Total length (m)	GT	Main engine (Hp)	Operations		Trips (n)	Tows (n)	Trawling hours
					Start	End			
Joana	São Tomé and Príncipe	60.0	890	1.700	26/10/2000	22/01/2001	2	300	1,073.2
Nuevo Apenino	Spain	33.0	308	540	17/09/2001	28/07/2002	9	932	3,474.7
Costa Grande	Spain	30.0	170	800	30/10/2002	29/07/2003	5	1,029	4,092.9
TB1	Mauritania	37.3	276	1.218	20/12/2004	10/09/2005	2	195	867.5
Kayar	Senegal	29.0	252	650	09/11/2004	18/09/2005	6	887	3,828.7
Lago Castiñeras	Spain	36.4	354	1.200	01/10/2004	03/11/2005	5	1,200	4,904.0
Favaios	Portugal	34.0	920	900	04/08/2004	26/09/2006	10	2,354	9,861.5
Nationalized	Brazil	31.1	---	870	05/09/2005	10/12/2006	9	1,521	6,003.7
Albamar	Spain	38.0	325	1.350	31/08/2004	29/05/2007	16	3,587	13,852.2
Mar Maria	Spain	38.4	271	1.200	28/08/2002	In operation	22	4,828	19,976.8
Total							75	15,601	63,387.3

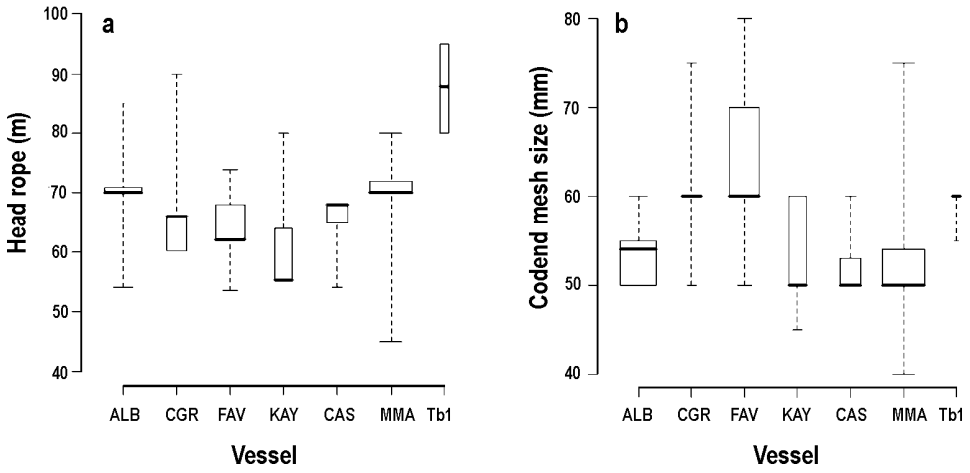

Figure 2. Distribution of the a) head rope length and b) codend mesh size used in the fishing nets for the capture of aristeid shrimps off Brazil between November 2002 and May 2007. The vessels are identified as: ALB (Albamar). CGR (Costa Grande), FAV (Favaios), KAY (Kayar), LCAST (Lago Castiñeras), MMA (Mar Maria), NOE (Noé), and TB1 (TB1). The box in the middle indicates the quartiles of the distribution and the median (horizontal line). The "whiskers" show the largest/smallest observations that fall within a distance determined to be 1.5 times the length of the box.

Figura 2. Distribución de a) las dimensiones de la relinga y b) de la malla del copo de la red utilizados en las redes de arrastre para la captura de gambas aristeideas en la costa de Brasil entre noviembre de 2002 y mayo de 2007. Se identifican los buques por las abreviaciones ALB (Albamar), CGR (Costa Grande), FAV (Favaios), KAY (Kayar), LCAST (Lago Castiñeras), MMA (Mar Maria), NOE (Noé) e TB1 (TB1). La "caja" central indica los quartiles de la distribución y la mediana (línea horizontal). Las lineas "wiskers" representan las mayores/ menores observaciones dentro de un rango definido como 1,5 veces el largo de la "caja".

shortfin squid *Illex argentinus* (49,887 kg) (Table 2). In addition, catches included a variety of discarded shellfish and finfish species typical of the lower slope. Although a comprehensive qualitative and quantitative analysis of discards has not been completed, the preliminary identification of specimens collected by observers included bonefishes of the family Synaphobranchidae, Macrouridae, Trachichtidae, Berycidae, Astronestidae, Oreosomatidae, Ipnopidae, Alocephalidae, Ophidiidae, and others. Invertebrates have also been frequently reported and collected, including deep-sea corals such as *Flabellum cf. alabastrum* (Pires, 2007).

Fishery history

The Portuguese vessel "Joana" was the first trawler to operate under the chartering program and reported the first catches of "alistado" shrimps in nine out of 300 trawls conducted in late 2000 – early 2001 (Figs. 4a and 4b). One of them at occurred at 32°S (300 m depth; 2.1 kg) and the others were recorded off the coast of the states of São Paulo and Rio de Janeiro at 23°S (384-460 m depth; 18.9 kg) (Table 3). In 2002, the trawler "Costa Grande" operating on slope areas (366.9 m ± 6.3 SE) and targeting mainly monkfish and hake concentrations (Fig. 4c) conducted exploratory trawls in areas deeper than 500 m on two occasions, resulting in new catches (177.3 kg) of aristeid shrimps, particularly in the vicinity of the 700 m isobath (Fig. 4d, Table 3). Also in 2002, the trawler "Nuevo Apenino", fishing for hake off the coasts of São Paulo and Rio de Janeiro states (Fig. 4e), conducted 27 trawls in areas deeper than 500 m; most of these produced positive catches of "carabinero" shrimps (Fig. 4f). These were the largest catches recorded during the early development phase (676.67 kg) and also the highest catch rates reported until then (8.9 kg hour^{-1} ± 2.5 SE) (Table 3).

Further concentrations of "carabinero" and "alistado" shrimps were also found in exploratory fishing conducted by the trawler "Mar Maria" in the northern sector of the Brazilian coast, off the coasts of the states of Amapá and Pará, between 1°-6°N and 45°-51°W (Asano-Filho *et al*., 2005; Pezzuto *et al*., 2006b; Perez *et al*., 2009a) (Table 3). Whereas all aristeid shrimp catches reported above were minor components of the total catches, they were profitable enough to stimulate a new fishing phase, the deepest

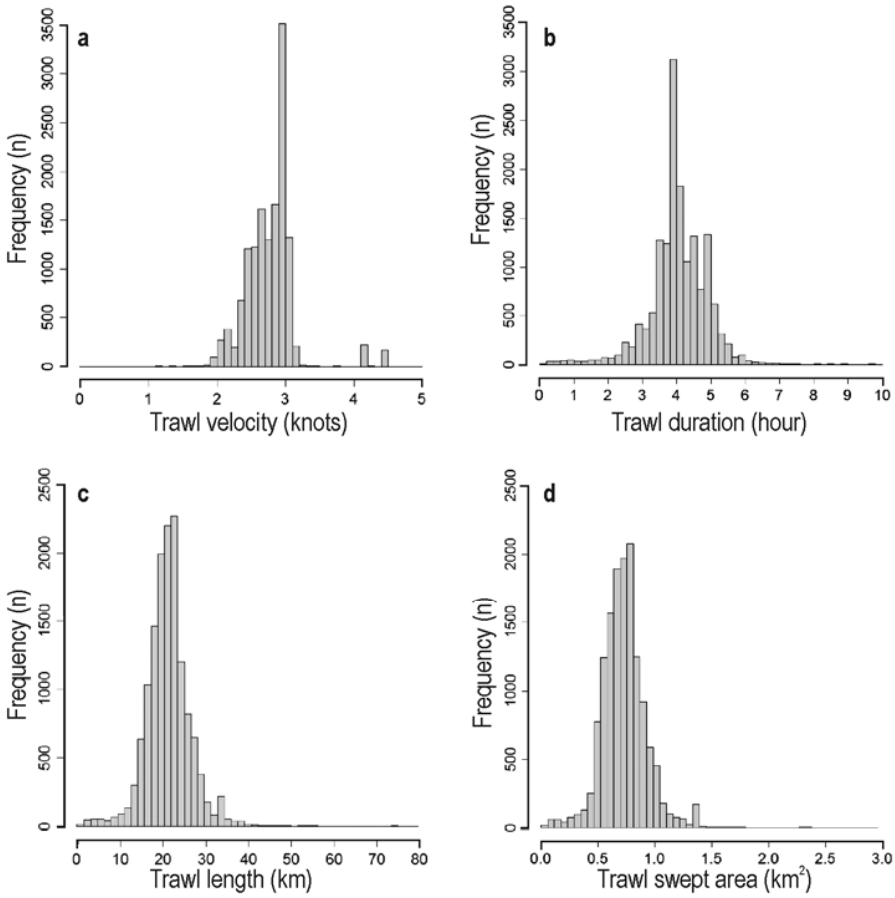

Figure 3. Fishing strategies adopted by the chartered trawlers for the aristeid shrimp fishery off Brazil between November 2002 and May 2007.

Figura 3. Estrategias de pesca empleadas por los arrastreros arrendados en la pesca de gambas aristeideas en la costa de Brasil entre noviembre de 2002 y mayo de 2008.

ever recorded in the country (Pezzuto *et al*., 2006b; Perez *et al*., 2009b). Thus, the chartered trawlers "Costa Grande" and "Mar Maria" pioneered the fishery, targeting aristeid shrimps in 2003 with lower slope trawling operations (Fig. 5). In the following year, as the former vessels abandoned Brazilian waters, five new trawlers entered the fishery under the chartering program composing, in 2003 and 2005, the largest fleet operating simultaneously on these slope areas. In 2006, this fleet was reduced to four units, including a new nationalized vessel. In 2007, only the latter vessel and "Mar Maria" maintained their operations on aristeid shrimps of Brazil (Fig. 5).

Until the end of 2004, the central (22-26ºS) sector concentrated all the fishing effort. In 2005, the new vessels "Favaios", "Albamar", "Lago Castiñeras", and "Kayar" started to fish in the northern (north of 22ºS) and southern (south of 26ºS) sectors, thereby expanding the fishery to the entire latitudinal extension of the slope off southeastern and southern Brazilian (Fig. 5).

The "carabinero" shrimp dominated the catches in all fishing sectors and was particularly abundant in the central sector and virtually the only species caught in the southern sector. The "moruno" shrimp, which is the second species in terms of total catches, was caught predominantly in the central sector, although catches in 2005 were considerably higher in the northern sector. The "alistado" shrimp was caught most abundantly in the northern sector throughout the entire fishing period (Table 4). The fishing effort was particularly concentrated in the central sector, peaking in 2005 with 2,911 trawls and 11,844 trawled hours exerted on this sector. In 2007, the effort tended to be evenly distributed throughout the entire fishing area.

Table 2. Annual fishing effort and catches (kg) of aristeid shrimp and the retained bycatch species off Brazil between 2002 and 2007. Data from 2007 are partial and include only the first semester.

Tabla 2. Esfuerzo anual de pesca y capturas (kg) de gambas aristeideas y especies de la captura accesoria en la costa de Brasil entre 2002 y 2007. Datos de 2007 son parciales e incluyen solamente el primer semestre.

Year	Trawling hours	Number of tows	*Aristaeopsis edwardsiana*	*Aristaeomorpha foliacea*	*Aristeus antillensis*	*Chaceon* spp.	*Meluccius hubbsi*	*Illex argentinus*	*Urophycis cirrata*	*Lophius gastrophysus*	Total catch (kg)
2002	935	238	13,021.0	0.0	0.0	4,584.0	35,001.5	40.0	1,786.1	5,448.0	64,680.0
2003	6,183.4	1,503	58,928.5	4,585.4	474.9	23,380.0	23,808.9	7,837.0	1,813.6	14,292.2	143,686.8
2004	9,737.3	2,276	81,585.1	14,861.4	5,489.1	30,322.0	4,090.8	0.0	2,742.3	225.0	139,901.7
2005	24,945.6	6,120	182,632.9	42,568.2	15,828.4	48,437.8	3,448.0	2,910.0	10,842.0	72.0	308,841.3
2006	18,372.3	4,608	99,325.3	51,756.4	5,365.4	18,056.5	4,735.0	39,100.0	7,267.0	340.0	226,730.1
2007	3,193.8	856	19,865.0	7,426.0	762.0	4,170.0	342.0	0.0	626.0	0.0	33,491.0
Total	63,367.3	15,601	455,357.8	121,497.4	27,919.8	128,950.3	71,426.2	49,887.0	25,077.0	20,305.21	917,258.9

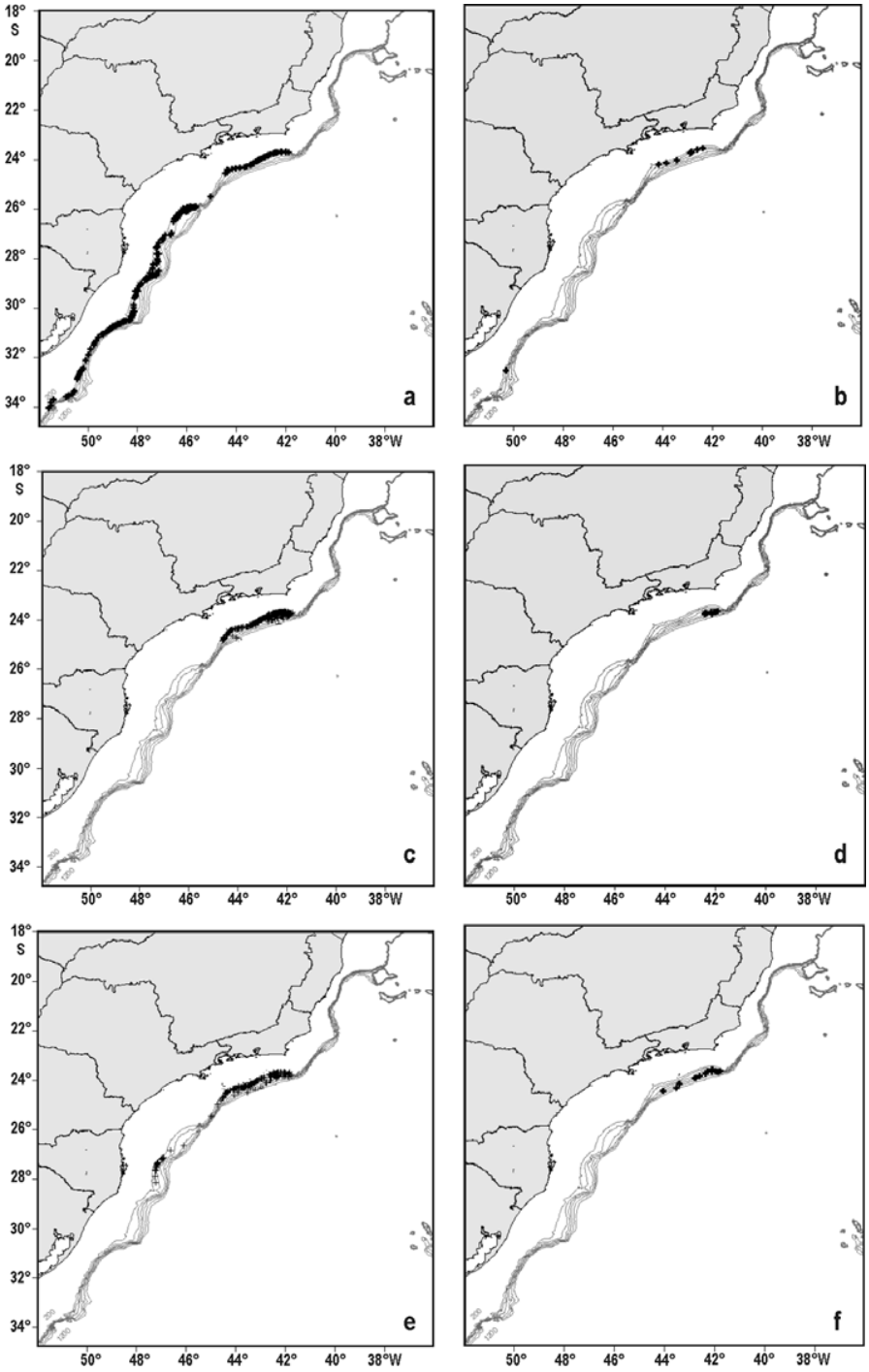

Figure 4. Geographic position of all fishing tows (left column) and of the fishing tows with incidental catches of aristeid shrimp fishery (right column) conducted by the vessels Joana (a and b), Costa Grande (c and d) and Nuevo Apenino (e and f).

Figura 4. Posición geográfica de todos los lances de pesca (columna de la izquierda) y de los lances de pesca con capturas incidentales de gambas aristeideas (columna de la derecha) realizados por los buques Joana, (a y b) Costa Grande (c y d) y Nuevo Apenino (e y f).

Table 3. Summary of aristeid shrimp bycatch off Brazil between 2000 and 2002.
Tabla 3. Resumen de las capturas accesorias de gambas aristeideas en la costa de Brasil entre 2000 y 2002.

Vessel (trips)	Fishing trip start	*Aristaeopsis edwardsiana* (kg)	*Aristaeomorpha foliacea* (kg)	Total catch (kg)
Joana (1)	26/10/2000	---	2.1	143,815.0
Joana (2)	16/12/2000	---	18.9	168,136.1
Costa Grande (1)	04/04/2002	166.7	---	297,838.9
Costa Grande (2)	17/05/2002	10.6	120.0	76,761.4
Nuevo Apenino (9)	15/06/2002	676.7	---	85,347.1
Mar Maria (1)	23/08/2002	498.5	207.6	51,427.8

Fishing grounds and intensity

In all fishing sectors, the trawls tended to concentrate on a narrow bathymetric stratum between 700 and 750 m depth (Fig. 6). An analysis of the distribution of fishing trawls on a finer spatial resolution allowed the definition of particular fishing grounds within the defined sectors where fishing activity was intense.

The central sector enclosed four localized fishing grounds intensely exploited since 2002 (Fig. 7a). The first trawling operations targeting "carabinero" shrimp concentrations occupied a northern fishing ground (C3). In the following year, the fishing area extended southwards, promoting the occupation of fishing grounds C1 and C2. By 2005, the last fishing ground (C4) was established in the northern extreme of this sector (Fig. 7a).

The exploitation of the northern sector began in 2004 and was concentrated in two well-defined fishing grounds (N2 and N4) (Fig. 7b). In the following year, a small fishing ground was established on the western side of the Besnard seamount, a component of the "Vitória-Trindade" chain (N3). In 2006-2007, a last fishing ground began to be exploited at the southern extreme of this sector (N1) (Fig. 7b). Three fishing grounds were exploited within the southern sector between 2005 and 2007 (S1, S2, S3) (Fig. 7c); a major submarine canyon separates S1 and S2.

The surface area of all the fishing grounds was limited, ranging between 125 km² and 1,227 km² (Table 5). In the central sector, the largest fishing grounds, C2 and C3, were trawled for almost 30,000 hours in total, accumulating nearly 45% of all fishing effort. The entire surface area of the fishing grounds C1, C2, and C3 was swept approximately two times. C4, the last ground to be fished by the trawl fleet, was swept 1.5 times over nearly one year of exploration (Fig. 8a). Most of the trawling efforts in the northern sector were concentrated in grounds N2 and N3 (Table 5). These grounds and N4 were fully swept at least 2.5 times, whereas N1 was swept 1.5 times. In the case of N3, which only began to be explored after mid-2005, the activity was much more intense than in the other grounds; in only six months, its surface area had been completely swept twice (Fig. 8b). In the southern sector, grounds S1 and S3 concentrated most of the trawling effort (Table 5) and had their entire surface areas swept once (Fig. 8c). Nevertheless, these grounds were less trawled than those of the central and northern sectors.

The largest catches of "carabinero" shrimps were recorded in fishing grounds C2 and C3. The largest catches of "moruno" shrimp originated from fishing grounds C3, C4, and N1. The largest catches of "alistado" shrimp were obtained in fishing grounds N2 and N4. In the central sector, the "carabinero" shrimp dominated the trawlers' catch except for the fishing ground C4, where "moruno" shrimp catches surpassed those of all other species (Table 5). However, an increasing proportion of the latter species was noticeable in the catches of 2006, particularly in fishing grounds C1, C2, and C3, as the proportion of "carabinero" shrimp declined (Fig. 9).

In the northern sector, this trend was not observed with the same clarity (Fig. 10). The proportion of shrimp species in the catches from fishing ground N1 remained stable, whereas the proportion of shrimp species alternated in the catches from fishing grounds N2, N3, and N4 (Fig. 10).

Catch rate

The "carabinero" shrimp sustained the highest mean catch (14 to 4.7 kg hour^{-1}) rates throughout the

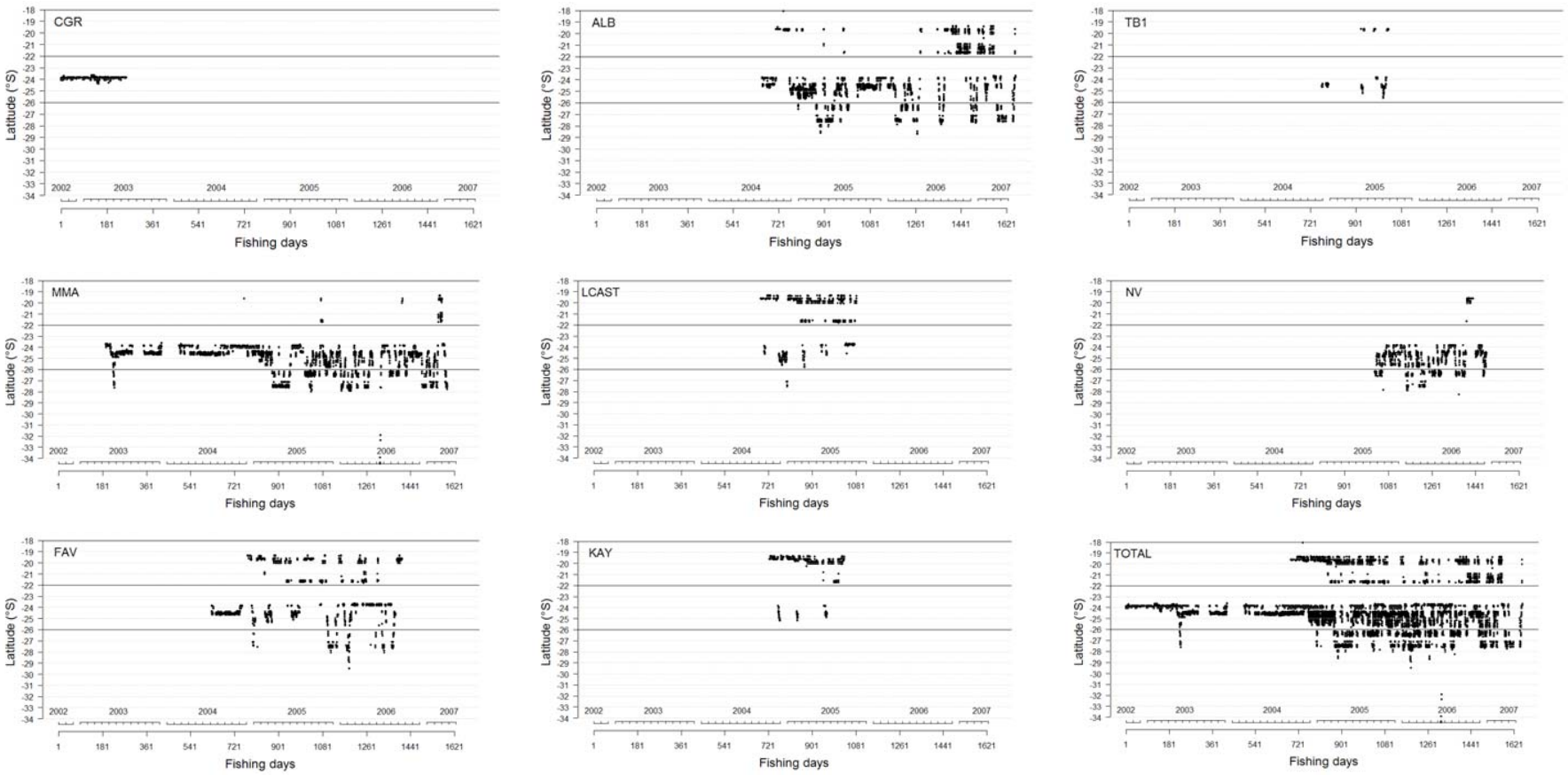

Figure 5. Daily fishing tows for the aristeid shrimp fishery off southeastern and southern Brazil. The first fishing day was 30 October 2002 and the last (1,673th) was 29 May 2007. Months and years are depicted over the x-axis. Each graph represents fishing operations of individual vessels denoted as: "Costa Grande" (CGR), "Mar Maria" (MMA), "Favaios" (FAV), "Albamar" (ALB), "Lago Castiñeras" (LCAST), "Kayar" (KAY), "TB1" (TB1), and Nationalized Vessel (NV).

Figura 5. Lances de arrastre diarios realizados para la captura de las gambas aristeideas en el sureste y sur de Brasil. El primer día de pesca fue el 30 de octubre de 2002. El último día (1.673) fue el 29 de mayo de 2007. Meses y años están representados sobre el eje x. Cada gráfico representa las operaciones de buques individualizados denotados como: "Costa Grande" (CGR). "Mar Maria" (MMA). "Favaios" (FAV). "Albamar" (ALB). "Lago Castiñeras" (LCAST). "Kayar" (KAY). "TB1" (TB1) y Barcos nacionalizados (NV).

Table 4. Geographic distribution of the fishing effort and catches of aristeid shrimps off Brazil between November 2002 and May 2007. Number of tows (tows); trawling hours (trawl); and catches of *Aristaeopsis edwardsiana*, *Aristaeomorpha foliacea* and *Aristeus antillensis*.

Tabla 4. Distribución geográfica del esfuerzo pesquero y capturas de gambas aristeideas en la costa de Brasil entre noviembre de 2002 y mayo de 2007. Número de arrastres (tows); horas de arrastre (trawl); capturas de *Aristaeopsis edwardsiana*, *Aristaeomorpha foliacea* y *Aristeus antillensis*.

		Year						
Operation sector		2002	2003	2004	2005	2006	2007	Total
Northern	tows (n)			521	2,163	869	290	3,843
	trawl (h)			2,141.2	8,957.7	3,126.4	907.3	15,132.6
	Aristaeopsis edwardsiana (kg)			21,317.9	58,300.0	19,177.9	6,413.0	105,208.9
	Aristeus antillensis (kg)			5,114.6	15,036.1	2,030.8	756.0	22,937.5
	Aristaeomorpha foliacea (kg)			1,652.1	27,191.0	19,151.3	4,552.0	52,546.5
Central	tows (n)	238	1,443	1,750	2,901	2,200	274	8,806
	trawl (h)	935	6,004.6	7,577.6	11,844.5	9,215.4	1,081.8	36,658.9
	Aristaeopsis edwardsiana (kg)	13,021	58,557.4	60,267.2	89,685.9	43,300.2	5,847.0	270,678.7
	Aristeus antillensis (kg)	0.0	474.9	374.5	775.9	3,306.6	6.0	4,937.9
	Aristaeomorpha foliacea (kg)	0.0	4,585.4	13,209.2	15,316.6	32,178.1	3,134.0	68,423.3
Southern	tows (n)		13		1,047	1,376	292	2,728
	trawl (h)		48		4,105.9	5,503.8	1,204.7	10,862.4
	Aristaeopsis edwardsiana (kg)		327.1		34,637.7	34,141.6	7,605.0	76,711.5
	Aristeus antillensis (kg)		0.0		8.2	26.0	0.0	34.2
	Aristaeomorpha foliacea (kg)		0.0		60.5	121.0	40.0	221.5
Northward of 18º 20'S	tows (n)		47	5	9	163		224
	trawl (h)		130.8	18.5	37.5	526.6		713.4
	Aristaeopsis edwardsiana (kg)		44.0	0.0	9.2	2,705.6		2,758.8
	Aristeus antillensis (kg)		0.0	0.0	8.2	2.0		10.2
	Aristaeomorpha foliacea (kg)		0.0	0.0	0.0	306.0		306.0
Total	tows (n)	238	1,503	2,276	6,120	4,608	856	15,601
	trawl (h)	935	6,183.4	9,737.3	24,945.6	18,372.3	3,193.8	63,367.3
	Aristaeopsis edwardsiana (kg)	13,021	58,928.5	81,585.1	182,632.9	99,325.3	19,865.0	455,357.9
	Aristeus antillensis (kg)	0.0	474.9	5,489.1	15,828.4	5,365.4	762.0	27,919.8
	Aristaeomorpha foliacea (kg)	0.0	4,585.4	14,861.4	42,568.2	51,756.4	7,726.0	121,497.3

entire period (2004-2007) (Fig. 11). These rates tended to decline locally and were generally higher as the different fishing sectors were exploited for the first time (Table 6).

Annually, mean catch rates declined steadily in all fishing sectors. In the central sector, mean catch rates decreased 61% between 2002 and 2007. The same was observed in the northern sector, where mean catch rates declined 36% from 2004 to 2006, increasing slightly in 2007. In the southern sector, catch rates dropped 26% in the first year of exploitation (2005-2006), stabilizing in 2007. "Carabinero" shrimp catch rates also exhibited seasonal variations, peaking every year in the fourth trimester. This pattern has been consistently observed in the central and southern sectors and is less pronounced in the northern sector.

The catch rates for "moruno" shrimp were generally lower than those of the "carabinero" shrimp (6.3 to 0.76 kg hour^{-1}) (Fig. 12). The annual variation of the former, however, exhibited a contrasting pattern in relation to the latter species *i.e.*, it tended to increase in the last years of deep-sea shrimp exploration. In the central and northern sectors, the catch rates increased 327% and 835% from 2002 to 2006 (Table 6). In 2006, the "moruno" shrimp catch rates were comparable with those of the "carabinero" shrimp, unlike the early fishery, when the latter species was significantly more productive. Within-year catch rate variations

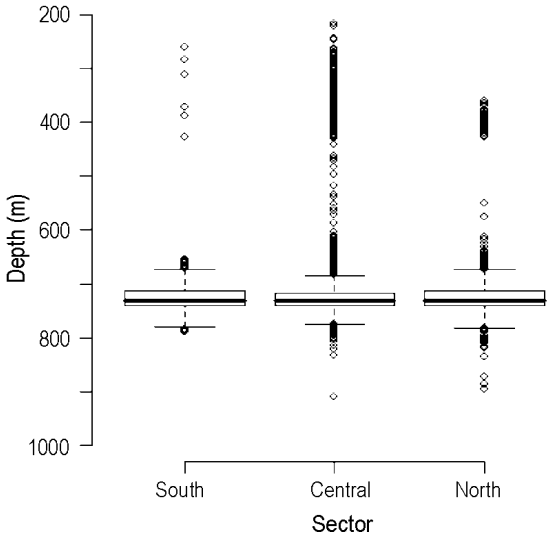

Figure 6. Distribution of individual tow depths in operations targeting aristeid shrimps off Brazil by latitudinal sector between November 2002 and May 2007. The box in the middle indicates quartiles of the distribution and the median (horizontal line). The "whiskers" show the largest/smallest observations that fall within a distance determined to be 1.5 times the length of the box. Observations falling outside the referred limits are shown separately as individual dots.

Figura 6. Distribución de las profundidades de los lances de pesca dirigidos a la captura de las gambas aristeideas por sector latitudinal en la costa de Brasil entre noviembre de 2002 y mayo de 2007. La "caja" central indica los quartiles de la distribución y la mediana (línea horizontal). Las líneas "whiskers" representan las menores/mayores observaciones dentro de un rango definido como 1,5 veces el largo de la "caja". Observaciones fuera de los límites referidos son representadas por separado como puntos individuales.

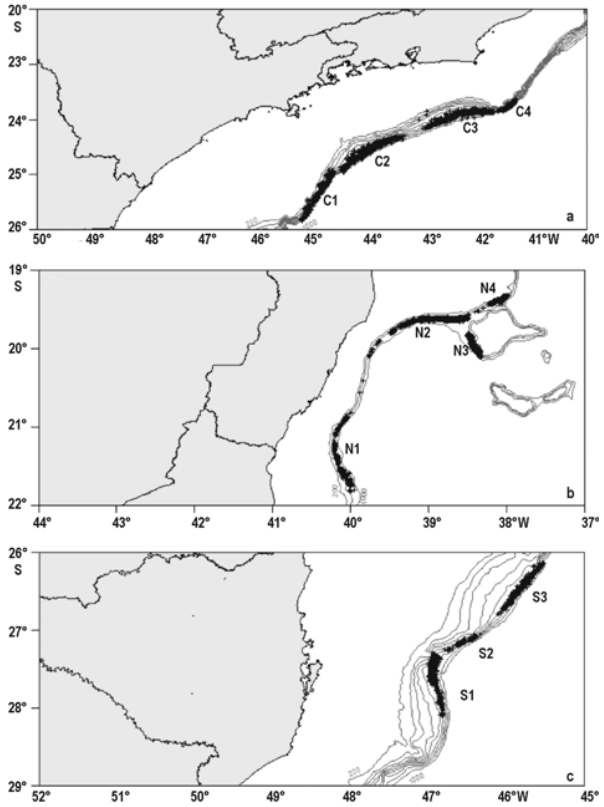

Figure 7. Fishing grounds on the middle slope of the a) central, b) north, and c) south sectors used by the chartered trawlers for the aristeid shrimp fishery off Brazil.

Figura 7. Áreas de pesca en el talud central de los sectores a) central, b) norte y c) sur utilizados por los arrastreros fletados en la captura de gambas aristeideas en la costa de Brasil.

were clearly distinguished in the northern sector, with peaks in the fourth trimester. In the central sector, seasonal variations were not as clearly defined, although lower catch rates were generally obtained for each year in the first trimester.

Catch rates of the "alistado" shrimp were, on average, the lowest among deep-sea shrimps (2.4 to 0.005 kg hour^{-1}) (Fig. 13). In the northern sector, however, the contribution of this species to the total aristeid shrimp catch was significantly higher than in the central sector, where it never surpassed 1.0 kg hour^{-1} (Table 6). In the northern sector, catch rates decreased around 65% between 2004 and 2007. In contrast with the other deep-sea shrimps exploited off Brazil, no within-year cyclic variation could be distinguished for the catch rate of "alistado" shrimps.

DISCUSSION

The descriptive analysis of the first five years of deep-sea shrimp exploration off Brazil revealed general patterns closely resembling aristeid fisheries elsewhere in the world. In French Guiana, the main fishing grounds are located between 400 and 900 m deep and most catches occur in the second half of the year in the vicinity of the 700 m isobath (Guéguen, 2000). Trawl surveys conducted in that area in 1990 obtained shrimp catch rates ranging between 13.2 and 40.6 kg hour^{-1} ("carabinero") and 0.09 and 0.74 kg hour^{-1} ("alistado") (Guéguen, 1998, 2000, 2001). In the Mediterranean Sea, the "gambero rosso" (*Aristaeomorpha foliacea*), known as "moruno" in Brazil, and "gamba rosada" (*Aristeus antennatus*), a species similar to the Brazilian "alistado" (*Aristeus antillensis*), have been reported to concentrate at 700 m depth close to the borders of submarine canyons. Seasonal fluctuations

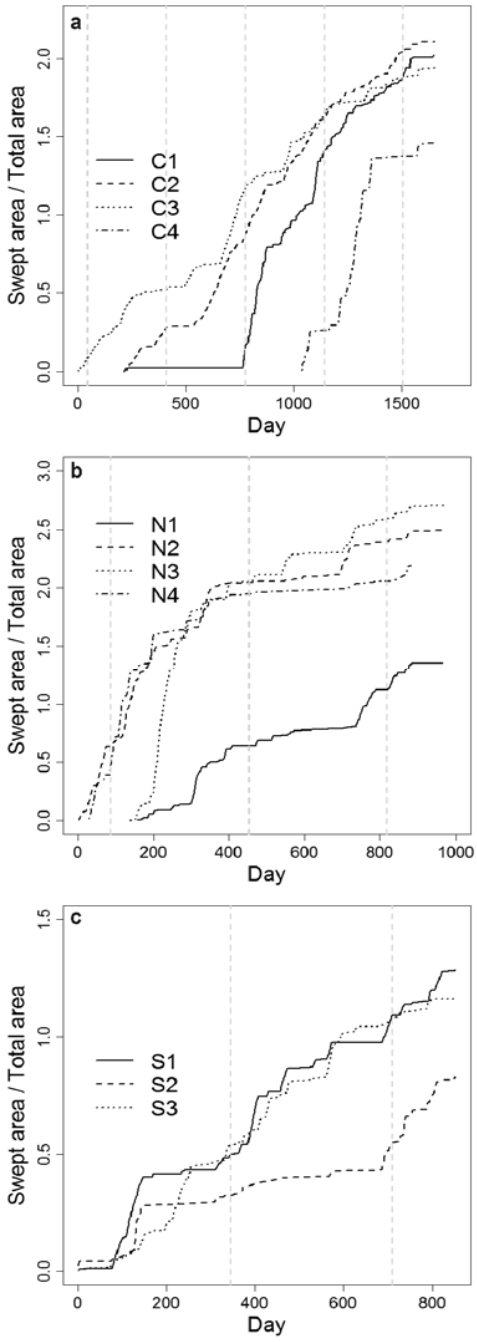

Figure 8. Cumulative curves of the area swept daily by the aristeid shrimp trawl fishery off Brazil. Values were weighted by the surface of each fishing ground within the latitudinal sectors a) south, b) central, and c) north. Vertical lines delimit the years of exploitation.

Figura 8. Curvas cumulativas de las áreas barridas diariamente por la pesca de arrastre dirigida a las gambas aristeideas en la costa de Brasil. Los valores fueron ponderados por la superficie de cada área de pesca dentro de los sectores latitudinales sur (a), central (b) y norte (c). Las líneas verticales delimitan los años de explotación.

in abundance have also been observed for both species; "gambero rosso" and "gamba rosada" are more productive in summer and winter-spring, respectively (Sardá, 2000). The highest catch rates of the "gambero rosso" shrimp were obtained off the coast of Algeria (around 12 kg hour^{-1}), whereas "gamba rosada" shrimps were more productive on the coast of Tunisia (around 15 kg hour^{-1}) (Sardà, 2000).

In other regions of the Mediterranean, catch rates have been considerably lower. In the NW Mediterranean, for example, a "gambero rosso" shrimp fishery was sustained for ten years (1991-2001) with catch rates oscillating between 4.55 kg hour^{-1} and 7.54 kg hour^{-1} (Carbonell & Azevedo, 2003). Off Brazil, deep-sea shrimp operations also concentrated around the 700 m isobath and catches included the "gambero rosso" exploited in the Mediterranean as well as the "alistado" (*Aristeus antillensis*) and "carabinero" (*Aristaeopsis edwardsiana*) shrimps also exploited off French Guiana. At least the "carabinero" and "moruno" shrimps showed seasonal concentrations in the main fishing areas and catch rates for all species ranged between 4.0 and 14.0 kg hour^{-1}, within the ranges reported for the aristeid fisheries above. Interestingly, scientific surveys conducted in 2004 in the northern extreme of the study area (northern sector) lead to the conclusion that these shrimps could not sustain economic exploitation on the basis of very similar catch rate levels obtained in most samplings (Costa *et al*., 2005). Whereas these levels are indeed remarkably lower than those generally sustained by coastal shrimps, the high market prices of aristeid shrimps allow a profitable commercial exploitation even in the long-term (more than 10 years) such as that observed in the Mediterranean fisheries (Carbonell & Azevedo, 2003).

Another similar pattern found between the Brazilian aristeid shrimp fishery and those sustained elsewhere in the world is the alternation of dominant species on the fishing grounds. Off the Brazilian slope, catches were generally dominated by the "carabinero" shrimp. As catch rates of this species decreased, possibly as a consequence of heavy fishing, other species, usually the "moruno", tended to exhibit higher proportions and to replace the "carabinero" in the catches. In the Gulf of Lion (Mediterranean Sea), the same scenario was observed on fishing grounds where the disappearance of "moruno" shrimp resulted in the increase of "alistado" shrimp in catches (Campillo, 1994 *fide* Cau *et al*., 2002), although ecological aspects related to this pattern are unclear. But it is possible that the species composition in the catches reflects the natural dominance pattern of the three species in the depth stratum exploited by the trawlers, which, in turn,

Table 5. Catches, fishing effort, and surface areas of the fishing grounds explored by the chartered trawlers targeting aristeid shrimps off Brazil between November 2002 and May 2007. NA: tows conducted outside the fishing grounds and north of 18º20'S.

Tabla 5. Capturas, esfuerzo de pesca y área de los fondos de pesca explotados por arrastreros arrendados para la pesca de gambas aristeideas en la costa de Brasil entre noviembre 2002 y mayo 2007. NA: arrastres realizados fuera de los fondos de pesca y al norte de 18º20'S.

Fishing grounds	Area (km²)	Tows (total number)	Trawling hours	*A. edwardsiana* (kg)	*A. foliacea* (kg)	*A. antillensis* (kg)
S1	766.808	1,383	5,701.7	41,858.9	61.2	24.7
S2	158.873	231	766.8	5,425.8	26.6	3.5
S3	496.853	1,096	4,334.2	29,324.8	133.8	6.0
C1	349.259	1,323	5,069.7	38,974.2	1,981.9	124.0
C2	1,226.655	3,811	16,207.4	124,660.1	16,472.1	1,297.5
C3	1,040.714	2,988	12,493.1	100,077.5	27,582.7	2,819.0
C4	202.300	404	1,794.7	6,822.8	22,386.6	697.4
N1	341.585	800	2,727.2	16,274.1	25,380.5	2,155.8
N2	463.798	1,682	6,769.7	47,427.7	9,308.8	9,413.2
N3	252.857	929	4,041.4	32,076.9	15,360.3	237.8
N4	124.521	412	1,538.1	9,090.4	2,481.3	11,098.5
NA		542	1,923.0	3,344.7	321.7	42.4
Total		15,601	63,367.1	455,357.8	121,497.4	27,919.8

Table 6. Annual mean yields (kg hour^{-1}) of *Aristaeopsis edwardsiana*, *Aristaeomorpha foliacea*, and *Aristeus antillensis* obtained by chartered trawlers within each latitudinal sector. Standard errors are given between brackets.

Tabla 6. Rendimientos anuales (kg hora^{-1}) de *Aristaeopsis edwardsiana*, *Aristaeomorpha foliacea* y *Aristeus antillensis* obtenidos por arrastreros arrendados dentro de los sectores latitudinales. Valores del error estándard entre paréntesis.

	Aristaeopsis edwardsiana			*Aristaeomorpha foliacea*		*Aristeus antillensis*	
Year	Central (kg hour^{-1})	Northern (kg hour^{-1})	Southern (kg hour^{-1})	Central (kg hour^{-1})	Northern (kg hour^{-1})	Central (kg hour^{-1})	Northern (kg hour^{-1})
2002	14.026 (± 0.830)	---	---	0.000	---	0.000	---
2003	9.380 (± 0.164)	---	---	0.774 (± 0.065)	---	0.082 (± 0.006)	---
2004	8.130 (± 0.116)	9.750 (± 0.257)	---	1.743 (± 0.088)	0.760 (± 0.053)	0.051 (± 0.004)	2.386 (± 0.193)
2005	7.686 (± 0.081)	6.468 (± 0.087)	8.492 (± 0.122)	1.264 (± 0.070)	3.084 (± 0.127)	0.062 (± 0.005)	1.757 (± 0.081)
2006	4.705 (± 0.055)	6.221 (± 0.123)	6.234 (± 0.090)	3.269 (± 0.180)	6.351 (± 0.270)	0.344 (± 0.034)	0.703 (± 0.055)
2007	5.380 (± 0.140)	7.076 (± 0.211)	6.362 (± 0.139)	3.046 (± 0.275)	5.088 (± 0.489)	0.005 (± 0.003)	0.825 (± 0.080)

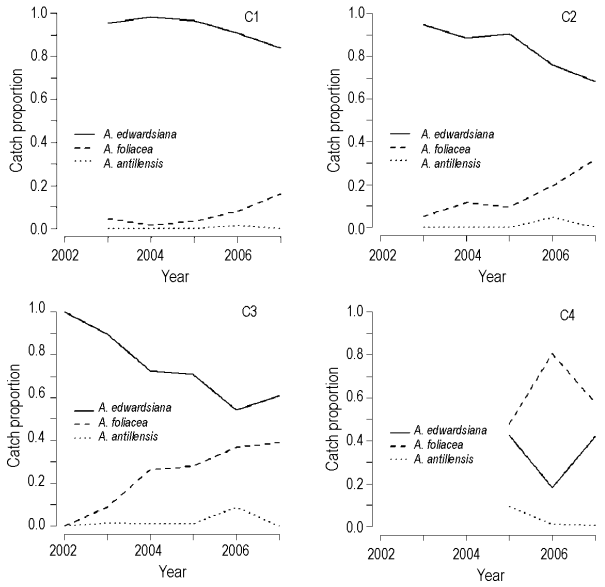

Figure 9. Relative composition of the three species of aristeid shrimps in annual catches obtained by operations in the fishing grounds of the central sector, southeastern Brazil. Data from 2007 refer to the first semester only.

Figura 9. Composición relativa de las tres especies de gambas aristeideas en las capturas anuales obtenidas en las áreas de pesca del sector central, sureste de Brasil. Datos de 2007 se refieren al primer semestre.

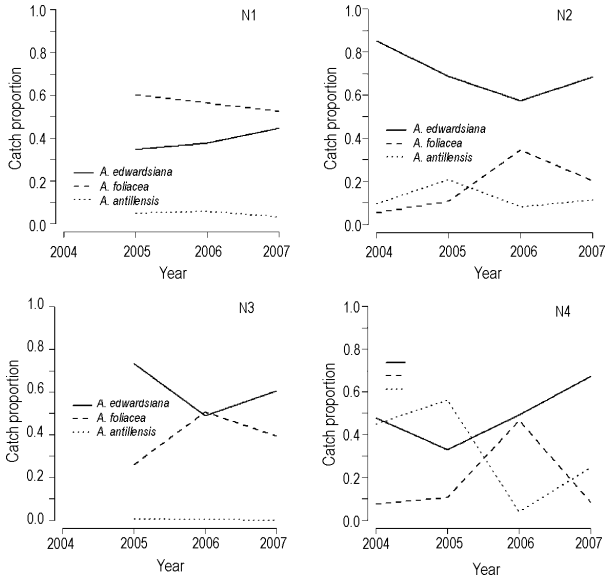

Figure 10. Relative composition of the three species of aristeid shrimps in annual catches obtained by operations in the fishing grounds of the north sector, southeastern Brazil. Data from 2007 refer to the first semester only.

Figura 10. Composición relativa de las tres especies de gambas aristeideas en las capturas anuales obtenidas en las áreas de pesca del sector norte, sureste de Brasil. Datos de 2007 se refieren al primer semestre.

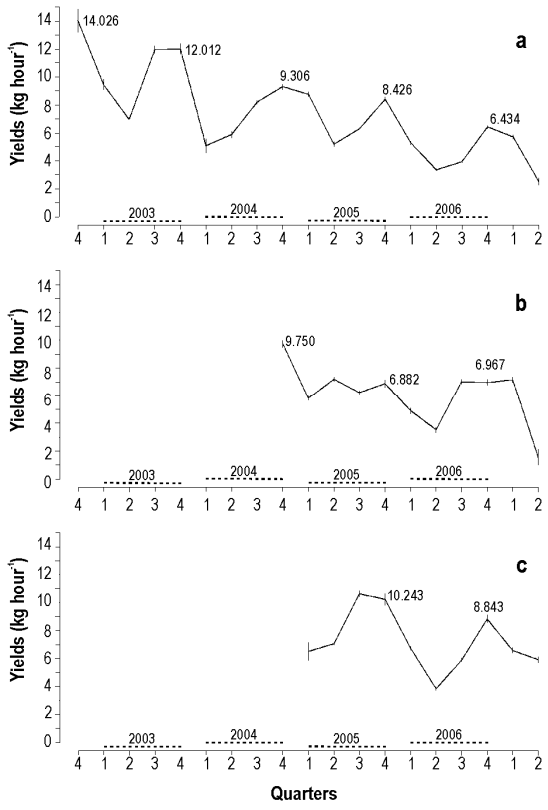

Figure 11. Mean yields (kg hour^{-1}) and standard errors (vertical bars) of *Aristaeopsis edwardsiana* for each quarter of the trawl fishery off Brazil in the a) central sector, b) north sector, and c) south sector.

Figura 11. Rendimientos medios (kg hora^{-1}) y error patrón (líneas verticales) de *Aristaeopsis edwardsiana* en cada trimestre de la pesquería de arrastre en la costra de Brasil. a) sector central, b) sector norte y c) sector sur.

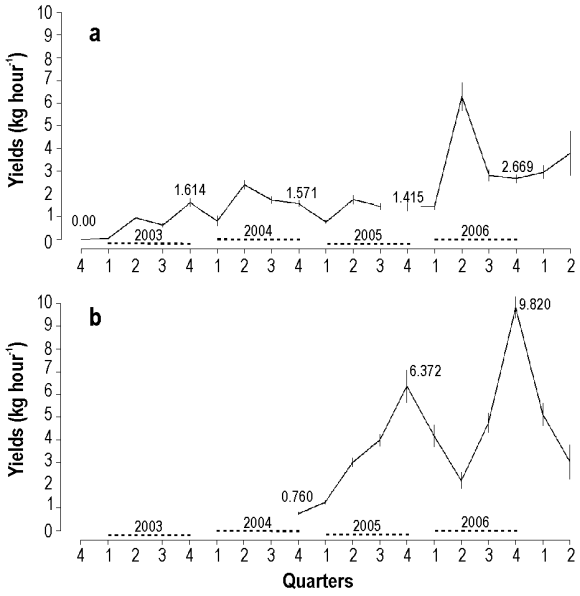

Figure 12. Mean yields (kg hour^{-1}) and standard errors (vertical bars) of *Aristaeomorpha foliacea* for each quarter of fishery off Brazil in the a) central sector and b) north sector.

Figura 12. Rendimientos medios (kg hora^{-1}) y error patrón (líneas verticales) de *Aristaeomorpha foliacea* en cada trimestre de la pesquería de arrastre en la costa de Brasil. a) sector central y b) sector norte.

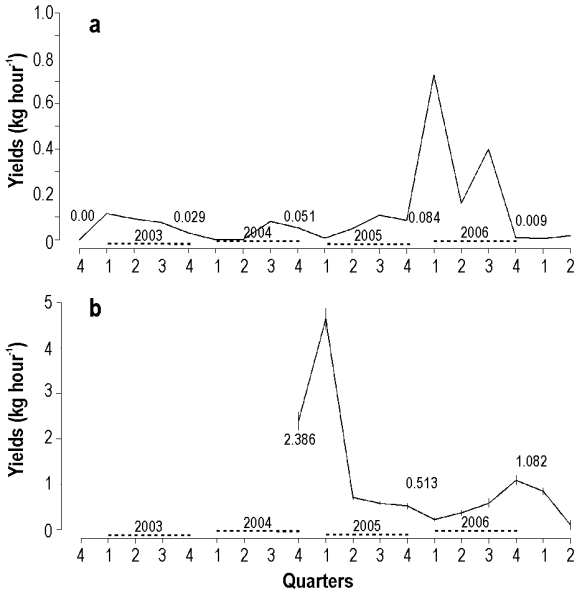

Figure 13. Mean yields (kg hour^{-1}) and standard errors (vertical bars) of *Aristeus antillensis* for each quarter of fishery off Brazil in the a) central sector and b) north sector.

Figura 13. Rendimientos medios (kg hora^{-1}) y error patrón (líneas verticales) de *Aristeus antillensis* en cada trimestre de la pesquería de arrastre en la costa de Brasil. a) sector central y b) sector norte.

may be part of the potential outcome of a competition process in the slope areas. In this process, "carabinero" shrimps might have naturally predominated the fishing areas of Brazil, whereas "moruno" and "alistado" shrimps may have been limited to deeper or adjacent areas not exploited by the fishery. Because the "carabinero" attains larger sizes and matures later in life, the species may be better fit for survival and out-compete the others within the 700-800 m stratum. Fishing first removes the highly vulnerable "carabinero" shrimp, opening space on the fishing grounds for smaller and possibly faster-growing "moruno" to expand their distribution. Studies conducted by Pezzuto & Dias (2007) revealed that the "moruno" shrimp has a continuous, year-round reproductive pattern, whereas the "carabinero" shrimp has defined, seasonal reproductive activity. Such distinct reproductive strategies may also provide evidence to support a possible dominance oscillation. Although mostly hypothetical at this point, such an interpretation is partially supported by the results of trawling surveys conducted in the northern sector of the study area (Serejo *et al*., 2007), revealing discrete bathymetrically-defined crustacean assemblages on the slope. Aristeid shrimps, which occur in areas as deep as 1,800 m, seem to con centrate in the rather narrow 500-700 m depth stratum, as also reported in other areas of the world (Cartes & Sardà, 1992).

Despite the biological and ecological similarities of these resources, fishery regimes have usually been established following different structural and motivational processes, including:

a) Long-term fisheries normally developed in combination with the seasonal availability of other demersal resources. In French Guiana, an aristeid fishery has been carried out for 20 years by a local fleet of small trawlers as a seasonal alternative to their main target, the coastal penaeid shrimp *Farfantepenaeus subtilis*. Catches are concentrated between June and November, when the abundance of *F. subtilis* decreases on the shelf areas and that of the "carabinero" increases on the middle and lower slope (Guéguen, 1998). In the Mediterranean Sea, this fishery has existed for more than 60 years, conducted by regional fleets of trawlers generally smaller than those operating under the chartering program in Brazilian waters. Mediterranean trawlers concentrate on aristeid shrimp as long as their density is sustained over profitable

levels, switching to other valuable resources otherwise (Maynou *et al.,* 2003; Company *et al*., 2008).

b) Opportunistic exploitation as valuable bycatch components of multispecies trawling operations. In Portugal, small catches of aristeid shrimps are part of a multi-specific, crustacean slope fishery (Monteiro *et al.*, 2001). Only in recent years has a directed fishery for aristeid shrimp been proposed due to its high market value and the overexploitation of traditional resources (Figueiredo *et al*., 2001).

c) Planned activities considering previously assessed local fishing potential. In Indonesian waters, a directed fishery for aristeid shrimp and other crustaceans only developed after stock assessment allowed for the definition of effort limits and maximum annual caches (Suman *et al*., 2006). On fishing grounds of the Ionian Sea, virginal populations of aristeid shrimps were intensely studied in order to subsidize the development of a directed fishery under precautionary effort limitations (Papaconstantinou & Kapiris, 2001, 2003).

None of the processes above can be directly related to the development of the Brazilian fishery for aristeid shrimps. In this case, the activity was induced by fishing authorities as a way of obtaining knowledge on stock distribution and availability, fishing and processing technology, and market opportunities (Perez *et al*., 2003). This process, however, was not ruled by precaution or a previous delimitation of the stock potentiality but was mostly profit-oriented, fast, uncontrolled, and disorganized. Since its early days, an excessive number of large vessels were allowed to concentrate in very limited areas of the central slope, and the most productive grounds were fully swept (once to twice) in a very short time. The exploration of new sectors of the Brazilian slope were only initiated as catch rates of the "carabinero" shrimp dropped below profitable levels in the central sector. Such exploration, however, followed the same "clean-up" strategy and produced similar local density reductions in the northern and southern slope sectors. Pezzuto *et al.* (2006b) analyzed this fishery between October 2002 and August 2004, warning about the negative consequences of the kind of fishing regime promoted by the chartered fleet. They concluded that operating large chartered trawlers in very restricted areas of the slope was only justifiable as long as it complemented existing information on deep-sea shrimp concentrations with data from still unexplored areas. In that sense, the interruption of the entry of new vessels into the fishery was recommended, along with the establishment of a rotating harvesting strategy that would allow the effort to spread along the Brazilian EEZ. As demonstrated, however, the deep-sea shrimp fishery developed off Brazil after 2004 regardless of these recommendations. In 2007, only two vessels were operating, a natural consequence of the major reduction of catch rates verified in most exploited fishing areas. Although producing timely estimates for a valuable and sustainable fishery development, this process rendered a biologically unsafe and unsustainable scenario and proved to be a dangerous strategy, particularly when directed at fragile deep-sea resources. Whereas the fishing regime established for the aristeid shrimps off Brazil seems to be clearly incompatible with sustained activity, its continuity under any of the patterns described elsewhere in the world will depend on severe restrictions to the total effort and a complete plan for biomass restoration on most productive grounds.

ACKNOWLEDGEMENTS

The authors are thankful to the Brazilian Government (SEAP/PR/001/2003; SEAP/PR/078/2004; SEAP/PR/064/2005; SEAP/PR/027/2007), the team of fisheries observers, and the staff of "Grupo de Estudos Pesqueiros" for making available information indispensable to this study.

REFERENCES

Asano-Filho, M., F.C.A.F. Holanda, F.J.S. Santos & T.S.C. Júnior. 2005. Recursos pesqueiros de grandes profundidades na costa norte do Brasil. IBAMA, Brasília, 81 pp.

Carbonell, A. & M. Azevedo. 2003. Application of non-equilibrium production models to the red shrimp (*Aristeus antennatus* Risso, 1816) fishery in the northwestern Mediterranean. Fish. Res., 65: 323-334.

Cartes, J.E. & F. Sardà. 1992. Abundance and diversity of decapods crustaceans in the deep-Catalan Sea (western Mediterranean). J. Nat. Hist., 26: 1305-1323.

Cau, A., A. Carbonell, M.C. Follessa, A. Mannini, G. Norrito, L. Orsi-Relini, C.Y. Politou, S. Ragonese & P. Rinelli. 2002. MEDITS-based information on the deep-water red shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus* (Crustacea: Decapoda: Aristeidae). Sci. Mar., 66(2): 103-124.

Company, J.B., P. Puig, F. Sardà, A. Palanques, M. Latasa & R. Scharek. 2008. Climate influence on deep sea populations. PLoS ONE, 3(1): e1431. doi:10.1371/journal.pone.0001431.

Costa, P.A.S., A.S. Martins, G. Olavo, M. Haimovici & A.C. Braga. 2005. Pesca exploratória com arrasto de

fundo no talude continental da região central da costa brasileira entre Salvador-BA e o Cabo de São Tomé-RJ. In: P.A.S Costa & G. Olavo (eds.). Pesca e potenciais de exploração de recursos vivos na região central da Zona Econômica Exclusiva brasileira. Museu Nacional, Rio de Janeiro, pp. 45-165.

Figueiredo, M.J., I. Figueiredo & P. Machado. 2001. Deep-water shrimps (Crustacea: Decapoda) from off the Portuguese continental slope: an alternative future resource? Fish. Res., 51: 321-326.

Guéguen, F. 1998. Biologie de la crevette profonde *Plesiopenaeus edwardsianus* en Guyane française. Life Sci., 321: 757-770.

Guéguen, F. 2000. Distribution et abondance des crustacés decapods du talus continental (200-900 m) de Guyane française. Crustaceana, 73(6): 685-703.

Guéguen, F. 2001. Notes sur la biologie de la crevette de profondeur *Aristeus antillensis* en Guyane française. Life Sci., 324: 689-700.

Maynou, F., M. Demestre & P. Sánchez. 2003. Analyses of catch per unit effort by multivariate analysis and generalized liner models for deep-water crustacean fisheries off Barcelon (NW Mediterranean). Fish. Res., 65: 257-269.

Monteiro, P., A. Araújo, K. Erzini & M. Castro. 2001. Discards of the Algarve (southern Portugal) crustacean trawl fishery. Hydrobiologia, 449: 267-277.

Papaconstantinou, C. & K. Kapiris. 2001. Distribution and population structure of the red shrimp (*Aristeus antennatus*) on an unexploited fishing ground in the Greek Ionian Sea. Aquat. Living Resour., 14: 303-312.

Papaconstantinou, C. & K. Kapiris. 2003. The biology of the red shrimp (*Aristaeomorpha foliacea*) at an unexploited fishing ground in the Greek Ionian Sea. Fish. Res., 62: 37-51.

Perez, J.A.A. & R. Wahrlich. 2005. A bycatch assessment of the gillnet monkfish *Lophius gastrophysus* fishery off southern Brazil. Fish. Res., 72: 81-95.

Perez, J.A.A., P.R. Pezzuto & H.A. Andrade. 2005. Biomass assessment of the monkfish *Lophius gastrophysus* stock exploited by a new deep-water fishery in southern Brazil. Fish. Res., 72: 149-162.

Perez, J.A.A., R. Wahrlich & P.R. Pezzuto (2009a). Chartered trawling on slope areas off Brazil. Mar. Fish. Rev., 71(2): 24-36.

Perez, J.A.A., P.R. Pezzuto, R. Wahrlich & A.L.S. Soares. (2009b). Deep-water fisheries in Brazil: history, status and perspectives. Lat. Am. J. Aquat. Res., 37(3): 513-541.

Perez, J.A.A., R. Wahrlich, P.R. Pezzuto & F.R.A. Lopes. 2002a. Estrutura e dinâmica da pescaria do peixe-sapo *Lophius gastrophysus* no Sudeste e Sul do Brasil. Bolm. Inst. Pesca, 28(2): 205-231.

Perez, J.A.A., P. Pezzuto, H.A. Andrade, P.R. Schwingel, M. Rodrigues-Ribeiro & R. Wahrlich. 2002b. O Ordenamento de uma nova pescaria direcionada ao peixe-sapo (*Lophius gastrophysus*) no Sudeste e Sul do Brasil. Notas Téc. FACIMAR, 6: 65-83.

Perez, J.A.A., R. Wahrlich, P.R. Pezzuto, P.R. Schwingel, F.R.A. Lopes & M. Rodrigues-Ribeiro. 2003. Deep-sea fishery off Southern Brazil: trends of the Brazilian fishing industry. J. Northw. Atl. Fish. Sci., 31: 1-18.

Pezzuto, P. & M.C. Dias. 2007. Estrutura populacional e reprodução dos camarões-de-profundidade (Aristeidae) no talude do Sudeste e Sul do Brasil. Relatório Técnico apresentado a 5ª Sessão Ordinária do Subcomitê Científico do Comitê Consultivo Permanente de Gestão dos Recursos Demersais de Profundidade (CPG/Demersais)/SEAP/PR. DOC 21 SCCCPG 05 2007. Itajaí, 197 pp.

Pezzuto, P.R., J.A.A. Perez & R. Wahrlich. 2006a. O ordenamento das pescarias de caranguejos-de-profundidade (*Chaceon* spp.) (Decapoda: Geryonidae) no sul do Brasil. Bolm. Inst. Pesca, 32(2): 229-247.

Pezzuto, P.R., J.A.A. Perez & R. Wahrlich. 2006b. Deep-sea shrimps (Decapoda: Aristeidae): new targets of the deep-water trawling fishery in Brazil. Braz. J. Ocean., 54(2/3): 123-134.

Pires, D.O. 2007. The azooxanthellate coral fauna of Brazil. In: R.Y. George & S.D. Cairns (eds.). Conservation and adaptive management of seamount and deepsea coral ecosystems. University of Miami, Miami, pp. 265-272.

Sardà, F. 2000. Final report of the study: analysis of the Mediterranean (including North Africa) deep-sea shrimps fishery: catches. effort and economics. DG XIV, Project 97/0018: 1-162.

Serejo, C.S., P.S. Young, I.C. Cardoso, C. Tavares, C. Rodrigues, & T.C. Almeida. 2007. Abundância, diversidade e zonação dos crustáceos no taude da costa central do Brasil (11º-22ºS) coletados pelo Programa REVIZEE/ Score Central: prospecção pesqueira. In: P.A.S. Costa, G. Olavo & A.S. Martins (eds.). Biodiversidade da fauna marinha profunda na costa central brasileira. Museu Nacional, Rio de Janeiro, pp. 133-162.

Sparre, P. & S.C. Venema. 1997. Introduction to tropical fish stock assessment. FAO Fish. Tech. Pap., 306/1, Rev. 2: 440 pp.

Suman, A., F. Wudianto & G. Bintoro. 2006. Species composition, distribution, and potential yield of deep sea shrimp resources in the Western Sumatera of the

Indian Ocean EEZ of Indonesian Waters. Ind. Fish. Res. J., 12(2): 2-10.

Wahrlich, R., J.A.A. Perez & F.R.A. Lopes. 2004. Aspectos tecnológicos da pesca do peixe-sapo (*Lophius gastrophysus*) com rede de emalhar no sudeste e sul do Brasil. Bolm. Inst. Pesca, 30(1): 87-98.

Zembruscki, S.G. 1979. Geomorologia da margem continental sul brasileira e das bacias oceânicas adjacentes. In: H.A.F. Chaves. (ed.). Geomorfologia da margem continental sul brasileira e das áreas oceânicas adjacentes. Série Projeto REMAC 7, Rio de Janeiro. pp. 129-177.

Received: 4 Jun 2008; Accepted: 3 July 2009