

DEEP-SEA SHRIMPS (DECAPODA: ARISTEIDAE): NEW TARGETS OF THE DEEP-WATER TRAWLING FISHERY IN BRAZIL

Paulo Ricardo Pezzuto, José Angel Alvarez Perez & Roberto Wahrlich

Universidade do Vale do Itajaí
Centro de Ciências Tecnológicas da Terra e do Mar
(Rua Uruguai, 458, Caixa Postal 360, 88.302-202 Itajaí, SC, Brazil)
E-mail: pezzuto@univali.br

ABSTRACT

Following the recent expansion of the Brazilian fishery to slope fishing grounds, a new directed trawl fishery for aristeid shrimps emerged since mid 2002. *Aristaeopsis edwardsiana* has been the main component of the catches attaining 88.4% of total shrimp production. *Aristaeomorpha foliacea* and *Aristeus antillensis* have composed significantly smaller fractions of the landings (9.8 % and 1.8 % respectively). Two main grounds were located in the southeastern region (ca. 19° - 25°S) and one in the northern border of the Brazilian EEZ (ca. 4°30' - 5°N). Catches have been extremely concentrated between the 700 and 750 m isobaths. Mean catch rates of *A. edwardsiana* oscillated between 6.5 and 9.7 kg.h⁻¹. The other species have been caught at considerably lower rates (0.1 - 0.6 kg.h⁻¹ and 0.1 - 1.3 kg.h⁻¹, respectively). A seasonal pattern in *A. edwardsiana* catches is suggested, with maximum values obtained between July and December. While largely directed to the shrimps, incidental catches of the royal crab (*Chaceon ramosae*) attained, on average, 22 % of the total landings.

RESUMO

Seguindo a recente expansão da pesca brasileira para o talude continental, uma nova pescaria de camarões da família Aristeidae tem se desenvolvido desde meados de 2002. O camarão "carabineiro", *Aristaeopsis edwardsiana*, é o principal componente das capturas, alcançando 88,4 % da produção total de camarões. Os camarões "moruno", *Aristaeomorpha foliacea* e "alistado", *Aristeus antillensis*, compõem frações menores das descargas (9,8 % e 1,8 % respectivamente). Duas áreas principais de pesca foram descobertas na região Sudeste do Brasil (19° - 25°S) e uma no limite setentrional da ZEE do país (4° - 5°N). As capturas estiveram concentradas entre as isóbatas de 700 e 750 m. As taxas médias de captura de *A. edwardsiana* flutuaram entre 6,5 e 9,7 kg.h⁻¹. As outras espécies foram capturadas em taxas consideravelmente menores (0,1 - 0,6 kg.h⁻¹ e 0,1 - 1,3 kg.h⁻¹, respectivamente). Sugere-se uma sazonalidade nas capturas de *A. edwardsiana*, com valores máximos entre julho e dezembro. Apesar do direcionamento aos camarões, capturas incidentais do caranguejo-real (*Chaceon ramosae*) alcançaram uma média de 22 % das descargas totais.

Key words: Deep-sea fisheries; Deep-sea shrimps; Bottom trawling; Aristeidae; Brazil.

Palavras chave: Pesca profunda, Camarões-de-profundidade; Arrasto-de-fundo; Aristeidae, Brasil.

INTRODUCTION

Shrimps of the family Aristeidae comprise one of the most valuable deep-water fishing resources, particularly in the Mediterranean Sea, where at least two species - *Aristaeomorpha foliacea* (Risso, 1816) and *Aristeus antennatus* (Risso, 1816) - sustain highly profitable fisheries (Cau *et al.*, 2002; Belcari *et al.*, 2003; Sardà *et al.*, 2003a). In the Strait of Sicily only, landings in the order of 1,000 t of *A. foliacea* have sustained a US\$ 10 million per year fishery (Bianchini *et al.*, 2003). In the Tirrenian Sea the same species first trading price ranges from €20 to 30 per kg (Belcari *et al.*, 2003).

Species of this family were known to occur off the Brazilian coast (D'Incao, 1995; 1998) but their fishing potential was only verified in recent years as exploratory deep-water trawling produced the first commercial catches in both the northern and southeastern sectors of Brazilian EEZ. These operations were part of a deep-water fishing development program, launched by the Brazilian government in 1998, based on the chartering of foreign vessels by national companies and an intense technological and scientific monitoring of these commercial operations. Since 2000, chartered vessels using pots, bottom longlines, bottom gillnets and otter trawls, started to operate in 200 - 900 m deep areas off Brazil, and established the first deep-water fishing

regimes on under-exploited targets such as the monkfish (*Lophius gastrophysus*), geryonid crabs (*Chaceon notialis* and *C. ramosae*), Argentine hake (*Merluccius hubbsi*), Argentine squid (*Illex argentinus*) and other demersal resources (Perez *et al.*, 2002a, b; Pezzuto *et al.*, 2002; Perez *et al.*, 2003; Wahrlich *et al.*, 2004; Perez *et al.*, 2005; Perez & Wahrlich, 2005).

Aristeid shrimps were first caught incidentally by one of the chartered trawlers in late 2000 (Perez *et al.*, 2003). By the end of 2002 two other trawlers identified profitable concentrations along the slope grounds off southeastern Brazil, which stimulated a rapid development of directed operations aiming at the EU market demands for deep sea shrimps. Since then these shrimps, as recently observed for monkfish and geryonid crabs (Perez *et al.*, 2002a), have motivated the latest deep-water fishery phase in Brazil, whose high value has not only generated economic interest by national and international fishing industry but also an urgent demand for preliminary biological knowledge for upcoming management actions.

This work describes spatial and temporal patterns of the first exploitation episode of deep-water shrimps in Brazilian waters. These elements are the basis for the assessment of sustainable fishing levels of these shrimps as well as the general impact of trawl fishing on the Southwest Atlantic slope ecosystems.

MATERIAL AND METHODS

The data analyzed derived from two deep-water fishing monitoring systems, developed as part of a scientific cooperation program established between the Brazilian Government and the University of "Vale do Itajaí" (Santa Catarina, Southern Brazil). A Vessel Observer Program (Wahrlich, 2002) and a Fleet Tracking Program (Rodrigues-Ribeiro, 2002) provided fishing position, depth, duration and catch/by-catch composition data of commercial fishing trips conducted by chartered trawlers off Brazilian coast between October 2000 and August 2004. Additionally, observers registered the physical features of all vessels as well as the main gear dimensions and characteristics. In none of the fishing trips the presence of the observers influenced fishing strategies (*i.e.* latitude and depth choices, duration of the hauls, target species, etc.).

Effort was expressed as trawling hours and catch rates were expressed as $\text{kg}\cdot\text{hour}^{-1}$. Trawling duration and position were measured from the winch stop to the beginning of gear withdraw. Mean catch rates and respective standard errors were calculated by vessel/trip, month and depth strata. Because chartered vessels differed in their temporal fishing patterns and main targets, each of them had their deep-sea shrimp

catch analyzed separately. Usually only the vessel "Mar Maria" operated long enough as to allow temporal patterns to be examined.

RESULTS

Target Species

Chartered trawler operations off Brazilian coast targeted three deep-water shrimp species, all of them included in the family Aristeidae.

Aristaeopsis edwardsiana (Johnson, 1867), the "carabinero" or scarlet shrimp, is the largest-bodied of the three species, with a broad geographic distribution including Western Atlantic (from Newfoundland - Canada to Uruguay), Eastern Atlantic (from southern Portugal to South Africa), Indian and Indo-Pacific Oceans (Mozambique, Madagascar, Tanzania, Somalia, Indonesia, Japan and Australia), occurring over 200 to 1,850 m deep grounds (D'Incao, 1995). The species was caught in localized areas of the northern and southeastern sectors of Brazilian coast, between 243 and 1,158 m depths (mean = 727 ± 46 m) (Table 1, Fig. 1).

Aristaeomorpha foliacea (Risso, 1827), known as "moruno", "rasoso" or giant red shrimp is also broadly distributed, being recorded in the Western Atlantic from southern Massachusetts State (USA) to Rio Grande do Sul State (Brazil). In Eastern Atlantic, the species has been recorded from the Bay of Biscay (France) to South Africa, including the Mediterranean Sea. In the Indian and Indo-Pacific Oceans, the species has been recorded in Mozambique, Madagascar, Tanzania, Maldives Islands, Sri Lanka, Indonesia, Japan, New Zealand and Fiji Islands (D'Incao, 1995). Off Brazil, the species was caught commercially between the 538 and 779 m isobaths (mean = 719 ± 20 m), over localized grounds of the southeastern coast (Table 1, Fig. 1).

Aristeus antillensis A. Milne Edwards & Bouvier, 1909, is the third species commonly known as "alistado" shrimp whose occurrence was previously known for the Western Atlantic from Delaware State (USA) to the French Guiana, at depths ranging from 200 and 850 m. Exploratory fishing cruises of the REVIZEE Program (Living Resources of Brazilian EEZ - Brazilian Government) reported the species also in the coast of northern Brazil, along Pará and Maranhão States, between 406 and 626 m depths (Silva *et al.*, 2002). Chartered trawlers caught this species in 300 - 1000 m deep areas (mean = 716 ± 70 m), not only off northern Brazil but also in the southeastern sectors, along São Paulo and Rio de Janeiro States, extending significantly its West Atlantic southern distribution limit (Table 1, Fig. 1).

Table 1. Summary of fishing operations conducted by chartered trawlers that produced deep-water shrimp catches off Brazilian coast. Decimal latitude and longitudes and depths are expressed as ranges where these shrimps were caught. Except in the case of the vessel "Joana", only trips that had deep-sea shrimps among their targets were summarized. In the first trip of the vessel "Mar Maria" latitudes correspond to the Northern Hemisphere. Trawl duration values (hs) are expressed as means \pm SD. n.a.: not available. Other: include all other species retained.

Vessel	Trip		Latitude (°S)		Longitude (°W)		Depth (m)		Hauls		<i>Aristaeopsis edwardsiana</i>	<i>Aristaeomorpha foliacea</i>	<i>Aristeus antillensis</i>	<i>Chaceon ramosae</i>	Other	
	Number	Start	End	Min.	Max.	Min.	Max.	Min.	Max.	Number	Duration	(kg)	(kg)	(kg)	(kg)	(kg)
Joana	1	26/10/2000	12/12/2000	32.59	32.59	50.33	50.33	300	300	165	4.01 (1.46)	0	0	2	0	120,875
Joana	2	16/12/2000	22/1/2001	23.74	24.39	44.18	42.38	348	460	135	3.49 (0.90)	0	0	19	0	148,773
Nuevo Apenino	9	15/6/2002	29/7/2002	23.77	24.60	41.78	44.05	356	762	176	4.03 (1.13)	640	0	0	1,620	81,756
Costa Grande	2	17/5/2002	25/6/2002	23.90	23.92	42.35	42.38	729	762	170	4.49 (2.04)	0	0	120	270	76,312
Costa Grande	6	30/10/2002	1/12/2002	23.83	23.94	41.92	42.41	724	751	138	3.87 (1.65)	3,963	0	0	1,974	45,817
Costa Grande	7	8/12/2002	9/1/2003	23.86	24.58	41.99	42.75	727	754	140	4.20 (0.73)	11,198	0	0	3,424	144
Costa Grande	8	15/1/2003	4/3/2003	23.85	24.09	41.88	43.00	722	750	192	3.79 (0.39)	9,095	0	143	4,669	0
Costa Grande	9	12/3/2003	22/5/2003	23.85	24.04	41.22	42.90	728	746	297	4.03 (0.76)	4,337	830	10	4,269	34,545
Costa Grande	10	28/5/2003	29/7/2003	23.85	24.08	41.20	42.96	711	746	261	4.05 (0.34)	10,536	801	266	2,008	6,790
Mar Maria	1	23/8/2002	28/10/2002	4.31	5.15	47.45	50.43	428	1,158	226	2.80 (1.96)	498	0	208	0	51,428
Mar Maria	5	14/6/2003	15/9/2003	23.04	27.63	41.07	47.96	243	865	363	4.33 (0.86)	16,099	109	8	8,820	13,286
Mar Maria	6	7/10/2003	16/12/2003	5.05	24.67	34.93	44.15	627	797	240	3.99 (0.87)	9,852	1,186	29	2,390	636
Mar Maria	7	20/12/2003	12/1/2004	23.86	25.18	41.96	44.16	691	775	82	4.67 (0.90)	3,304	227	0	830	106
Mar Maria	8	23/3/2004	24/5/2004	23.83	24.67	41.83	44.14	667	777	244	4.59 (0.77)	5,906	2,344	0	7,482	1,707
Mar Maria	9	4/6/2004	9/8/2004	23.87	24.73	41.90	44.59	682	775	259	4.46 (0.71)	7,938	1,562	0	3,734	2,818
Mar Maria	10	16/8/2004	12/10/2004	23.09	24.77	41.90	44.27	695	768	250	3.69 (0.75)	8,590	1,414	92	2,690	9,655
Mar Maria	11	19/10/2004	30/11/2004	23.85	24.41	41.84	43.67	696	744	161	n.a.	7,563	1,812	73	1,430	455
Favaios	1	4/8/2004	24/10/2004	23.89	24.69	42.25	44.18	538	762	211	4.75 (0.51)	7,404	692	0	2,518	440
Albamar	1	31/8/2004	11/11/2004	19.43	24.70	38.22	44.18	658	809	274	4.19 (0.75)	7,979	1,795	510	3,444	401
Lago Castiñeiras	1	1/10/2004	13/11/2004	19.33	24.63	38.00	43.96	702	782	156	4.01 (1.16)	4,227	459	943	2,268	0
TOTAL											119,129	13,231	2,423	53,80	587,354	

Fishing Fleet and Total Catch

Commercial exploitation of deep-sea shrimps in Brazil by chartered vessels was preceded by incidental catches of *A. antillensis* obtained off Rio Grande do Sul State (32°S) by the Portuguese trawler "Joana" during its first authorized trip in Brazilian waters, in November-December 2000. In a subsequent trip, in January 2001, this vessel reported new catches of the same species further north, along Rio de Janeiro and São Paulo State coasts (23°S) (Table 1). In both occasions, catches did not exceed a few kg and were concentrated in areas above the 500 m isobath.

Important catches were only obtained in mid 2002, when new chartered trawlers started their operations in areas deeper than 700 m. Since then two Spanish vessels, "Mar Maria" and "Costa Grande", conducted systematic operations targeting mostly *A. edwardsiana*, the latter departing from Brazilian waters in July 2003 (Table 1). From mid 2004 onwards, deep-sea shrimp trawling was intensified as the newly-chartered Spanish trawlers "Albamar", "Favaios" and "Lago Castiñeiras" along with the Senegalese "Kayar I" and the Mauritanian "TB1" entered the fishery (Table 2). Presently, two additional trawlers under Brazilian flag, "Noé" and "Capitão Lucas", have completed an eight unit trawling fleet directed towards *A. edwardsiana* and other deep-sea

shrimp fishing. Unlike the chartered trawlers, however, these national vessels have not been required by law to be observed or tracked by VMS and very little is known of their operations.

Total production of deep-sea shrimps have increased systematically since 2000 as the number of trawlers in operation augmented and new fishing grounds were identified. Until November 2004 total landings of the three species pooled reached 134.8 t, mostly composed of whole shrimp and a minor fraction (less than 10%) of processed "tails". *A. edwardsiana* has been the main component of the catches attaining 88.4% of total shrimp production. *A. foliacea* and *A. antillensis* have composed significantly smaller fractions of total shrimp landings (9.8 % and 1.8 % respectively) (Table 3).

All three species combined made up 60% of the total landings, on average, considering only those trips that had deep-sea shrimps as their main target (ranging from 11% to 83%) (Table 1). Secondary components in these landings were chiefly the royal crab (*Chaceon ramosae*), reaching, on average, 22 % of the landings (ranging from 10% to 43%), and other shellfish and finfish species such as the Gulf hake (*Urophycis cirrata*), the Argentine hake (*Merluccius hubbsi*), the Argentine squid (*Illex argentinus*) and other species that together made up 18 % of the landings (ranging from 0 to 78%) (Table 1).

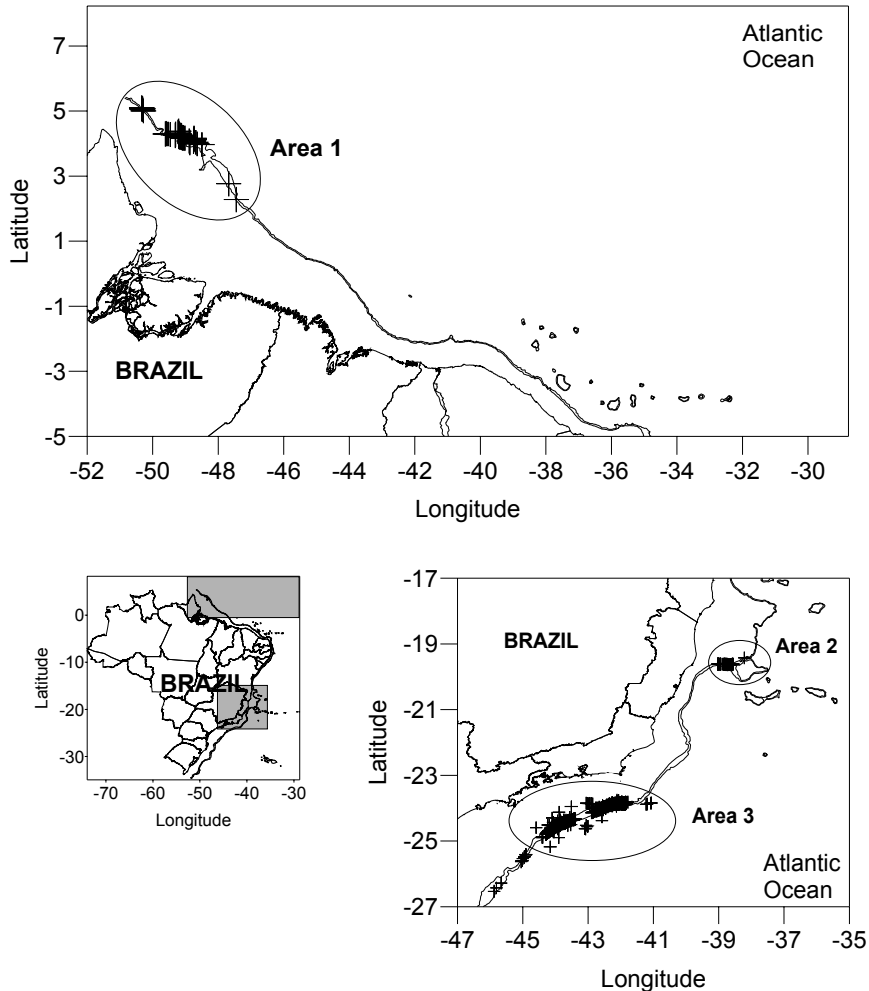


Fig. 1. Distribution of deep-sea shrimp catches reported by chartered trawlers between 2000 and 2004. Main fishing areas are encircled. Isobaths of 500 and 1000 m are shown in all maps.

Fishing Areas

Most deep-sea catches have originated from operations off southeastern Brazil, between Rio de Janeiro and São Paulo State coasts (*ca.* 24° to 25°S) (Area 3, Fig. 1). Productive concentrations have also been found by the trawler “Mar Maria” off northern Brazil (Area 1, Fig. 1), where both *A. edwardsiana* and *A. antillensis* were caught.

Trawlers entering the fishery during the second half of 2004 concentrated their operations directly in area 3 where favorable yields were previously known. However, as this geographically limited area became excessively crowded, some

vessels performed exploratory trawls northwards, where a new productive fishing ground (Area 2, Fig. 1) was identified, east of Espírito Santo State (*ca.* 19°30' - 20°S). Since then, the exploitation of this area has implied in a significant spreading of fishing effort.

Despite the vast area explored by the chartered fleet since 2000 and the relatively wide bathymetric range where deep-sea shrimps were found to occur, commercial catches of all three species have been extremely concentrated in a restricted depth stratum, delimited by the 700 and 750 m isobaths. Between 76% and 88% of all positive trawls were conducted within this stratum (Fig. 2).

Table 2. Physical and operational features of the chartered trawlers that caught deep-sea shrimps off Brazilian coast from 2000 to 2004.

Vessel	Origin	Total Length (m)	GT	Main engine (Hp)	Operations	
					Start	End
Albamar	Spain	38.0	325	950	25/08/2004	-
Costa Grande	Spain	30.0	170	800	03/04/2002	31/07/2003
Favaio	Portugal	34.0	920	900	28/07/2004	-
Joana	São Tome and Príncipe	60.0	890	1700	25/10/2000	23/01/2001
Kayar 1	Senegal	29.0	252	650	05/11/2004	-
Lago	Spain	36.4	354	1000	29/09/2004	-
Castineras						
Mar Maria	Spain	38.4	271	1200	23/08/2002	-
Nuevo	Spain	33.0	308	540	10/09/2001	30/07/2002
Apenino						
TB1	Mauritânia	37.3	276	1218	12/11/2004	-

Table 3. Deep-sea shrimp annual landings (in kg) produced by chartered trawlers between 2000 and 2004.

Year	<i>Aristaeopsis edwardsiana</i>	<i>Aristaeomorpha foliacea</i>	<i>Aristeus antillensis</i>	Total
2000	0	0	2	2
2001	0	0	19	19
2002	4,603	0	120	4,723
2003	61,615	2,926	664	65,205
2004	52,911	10,305	1,618	64,834
Total	119,129	13,231	2,423	134,783

Catch Rates

Both total catch and catch rates differed significantly among the three deep-sea shrimp species (Table 4). While mean catch rates of *A. edwardsiana* oscillated between 6.5 and 9.7 kg.h⁻¹, *A. foliacea* and *A. antillensis* have been caught at considerably lower rates, on average, with some localized elevated catch-rates being obtained specially for the second species.

The catch rate series obtained by the trawler "Mar Maria", which targeted deep-sea shrimps for a longer period and in a broader area than any other chartered vessel in Brazilian waters, indicated that the highest mean catch rates of *A. edwardsiana* (higher than 8.0 kg.h⁻¹) were obtained between the 600 and 800 m isobaths. These rates declined both towards shallower and deeper grounds, being particularly small in trawls above 600 m depths where catch rates were lower than 1.0 kg.h⁻¹ (Fig. 3). The highest catch rates of *A. foliacea* and *A.* were obtained in 600 - 700 m and

700 - 800 m depth strata respectively, also with important reductions outside these limits (Fig. 3).

A continuous catch rate series of the trawler "Mar Maria" from June 2003 to October 2004 indicated a likely seasonal pattern in the *A. edwardsiana* catch, with maximum values (over 9.0 kg.h⁻¹) obtained between July and December and rates as low as 5 kg.h⁻¹ obtained between January and July (Fig. 4).

DISCUSSION

Marine shrimps were incorporated into the Brazilian fishing industry during late 1960's and are represented by species of the family Penaeidae such as the pink-shrimp *Farfantepenaeus subtilis* (Pérez-Farfante, 1967) in the northern coast (Aragão *et al.*, 2004), the sea-bob-shrimp *Xiphopenaeus kroyeri* (Heller, 1862) mostly in the southeastern coast (Valentini *et al.*, 1991a; D'Incao *et al.*, 2002) and the

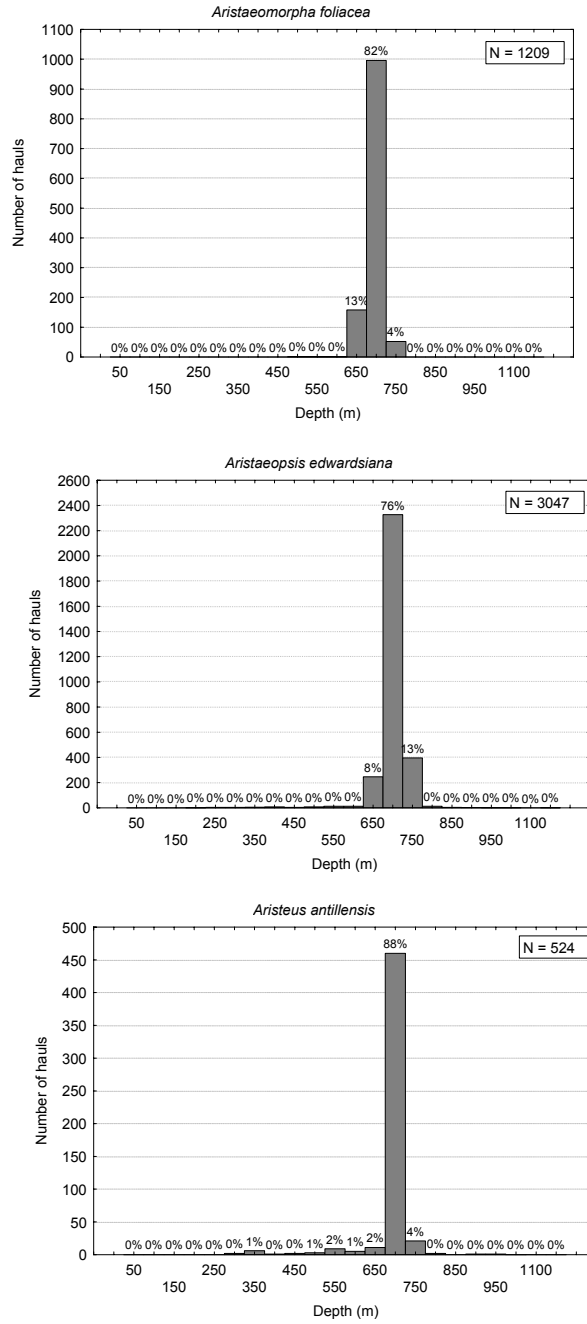


Fig. 2. Bathymetric distribution of positive catches of deep-sea shrimps obtained by the chartered fleet off Brazil between 2000 and 2004.

pink-shrimps *F. paulensis* (Pérez-Farfante, 1967) and *F. brasiliensis* (Latreille, 1817) off southeastern and southern Brazil (D'Incao *et al.*, 2002). As the abundance of the two latter species principally declined, trawling became a multispecies activity and other coastal shrimps, *Artemesia longinaris* Bate 1888 and *Pleoticus muelleri* (Bate, 1888), were further

included among other targets (Perez & Pezzuto, 1998). Both species have been extensively caught along the coast of Rio Grande do Sul State where they have produced economic returns comparable to those traditionally obtained by the pink-shrimp catches (Perez *et al.*, 2001; D'Incao *et al.*, 2002; Perez *et al.*, 2003).

Table 4. Deep-sea shrimp catch-rate ($\text{kg}\cdot\text{h}^{-1}$) patterns obtained by chartered trawlers off Brazilian coast between 2000 and 2004. Mean, Standard Errors (SE), minimum (Min) and maximum (Max) values were extracted from vessels and trips that had these shrimps as their main target. In the case of the vessel "Mar Maria" only those trips and trawls conducted at the southeastern sector of Brazilian coast are included.

Vessel	<i>Aristaeopsis edwardsiana</i>			<i>Aristaeomorpha foliacea</i>			<i>Aristeus antillensis</i>			Number of hauls
	Mean	SE	Min-Max	Mean	SE	Min-Max	Mean	SE	Min-Max	
Mar Maria	8.41	0.14	0 - 52.80	0.18	0.01	0 - 6.27	0.02	0.01	0 - 1.52	1451
Costa Grande	9.66	0.26	0 - 46.00	0.20	0.03	0 - 11.49	0.10	0.01	0 - 2.68	1027
Albamar	6.81	0.29	0 - 27.00	0.21	0.03	0 - 5.28	0.44	0.04	0 - 4.80	274
Favaios	7.07	0.27	0 - 17.78	0.07	0.01	0 - 1.55	-	-	-	211
Lago Castiñeras	6.52	0.35	0 - 26.45	0.59	0.10	0 - 11.98	1.32	0.18	0 - 13.97	156

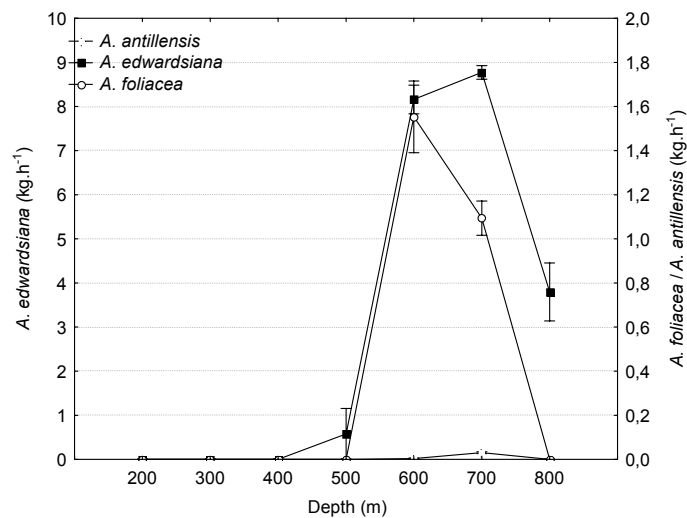


Fig. 3. Mean catch rate ($\pm\text{SE}$) obtained by the trawler "Mar Maria" during fishing trips directed towards deep-sea shrimps off the southeastern coast of Brazil.

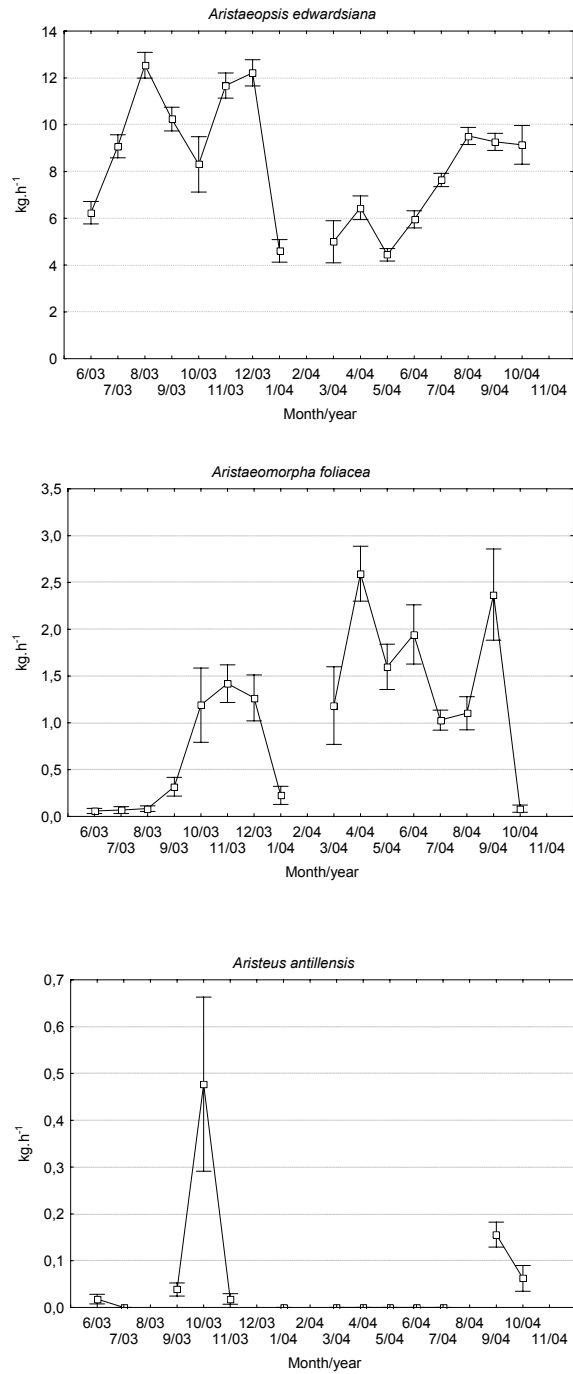


Fig. 4. Deep-sea shrimp mean catch rate (\pm SE) temporal variation obtained by the vessel "Mar Maria" off southeastern Brazil.

These are coastal species that rarely occur in areas deeper than 70 m, as in the case of the pink-shrimp (Dias Neto, 1991; Valentini *et al.*, 1991a; 1991b). Hence, historically motivated by such targets, national shrimp trawlers have adapted their gear and fishing operations to the extensive flat areas that predominate on the continental shelf in the northern, southeastern and southern sectors of Brazilian EEZ. Limited hull and winch dimension, low powered main engines and the use of the double-rig nets, for instance, feature among these adaptations which, in turn, are hardly compatible to operations in deeper grounds where aristeid shrimps concentrate. In fact, and as observed in other areas of the world (Roberts, 2002), during the last four years, a considerable part of these fleet extended their operations to shelf break areas as valuable concentrations of the monkfish, the Gulf hake, the Argentine squid and other underexploited demersal species became highly attractive, in particular, to compensate for the economic losses produced by the generally collapsed coastal resources (Perez *et al.*, 2002a). Such expansion, however, did not surpass the 350 – 400 m isobaths, due to the technological limitations referred above.

A similar scenario has been described in the coast of French Guiana where double-rig shrimp trawlers have targeted deep-sea shrimps during the dry-season, as catch rates of the coastal pink shrimp (*F. subtilis*) decrease. While profitable, these operations, however, have been often limited by technological/operational restraints (Guéguen, 2000). Such restraints were only overcome by the fishing industry in Brazil through the chartering of foreign trawlers capable of operating on fishing grounds over 500 m deep (Perez *et al.*, 2003). Hence, unlike what has been observed in northwestern Mediterranean Sea, where deep-sea shrimps have been exploited for over 60 years (Sardà & Cartes, 1994), the exploitation of these shrimps off the Brazilian coast has only initiated after 2000.

Deep-sea fishing in Brazil has been conducted by a limited number of medium-sized factory vessels (longer than 30 m and with main engines ranging from 540 to 1200 HP) that operated 60 to 90 day trips, in a 24-hour regime, performing under four trawls per day, each one over four hours long. These fishing patterns are somewhat contrasting with those reported for traditional deep-sea shrimp fisheries elsewhere, such as the Mediterranean and off Australian coast, particularly as trips in the Brazilian fishery seem to have been longer and vessels slightly larger. Off Barcelona (N W Mediterranean) *Aristeus antennatus* fishing has been conducted by 17 to 21 m long trawlers powered by 800-1100 HP main engines. This fleet operates only five days a week, performing

typically two 3.5 hour long trawls per day always during daytime (Sardà & Maynou, 1998; Sardà *et al.*, 2003a). Around Mallorca Island, there are around forty deep-sea shrimp vessels powered by engines ranging from 200 to 450 HP (Carbonell, 1994). In the Sicilian Channel, *Aristaeomorpha foliacea* is caught by 100 trawlers with up to 1000 HP engines that conduct 2 to 3 week long trips and 3 to 4 hour long trawls (Ragonese *et al.*, 1994). Finally in NW Australia, the same species is caught by shrimp trawlers approximately 25 m long, employing nets adapted from coastal penaeid shrimp fisheries. These vessels conduct 4 week fishing trips nearly when 4 hour long trawls are normally carried on (Wadley, 1994).

The exploratory scenario of the incipient commercial deep-sea fishing off Brazil, including remote poorly known fishing grounds, may have justified the incidence of robust vessels and long fishing regimes. As fishing areas, effort patterns and market demands become well established, fleet structure and fishing operation changes may be expected in the direction of economic optimization.

Despite fishing particularities, mean catch rates obtained in Brazil, principally of *A. edwardsiana*, lay within ranges reported for Aristeid shrimps either by commercial operations or exploratory surveys worldwide. In the Mediterranean, *Aristeus antennatus* mean catch rates have oscillated between 3.3 and 4.9 kg.h⁻¹ off Murcia (Baños, 1994), 4 and 25 kg.h⁻¹ around Mallorca Island (Carbonell, 1994) and 6.3 and 10.9 kg.h⁻¹ off Barcelona (Sardà *et al.*, 1997). Along the Portuguese continental slope, yields from the same species have varied from 0.01 to 8.0 kg.h⁻¹ (Figueiredo *et al.*, 2001). According to Ragonese *et al.* (1994), *A. foliacea* catch rates obtained by experimental trawling in the Sicilian Channel attain 3 kg.h⁻¹ although historical records include 25 kg.h⁻¹ in the early 1960's, 8 kg.h⁻¹ in 1972 and 5 kg.h⁻¹ in 1984. Catch rates from 0.01 to 9.6 kg.h⁻¹ and between 25 to 50 kg.h⁻¹ have been obtained for the latter species during research surveys conducted off Portugal and by commercial trawlers operating in the NW Australia, respectively (Wadley, 1994; Figueiredo *et al.*, 2001). Exploratory and commercial operations reported by Guéguen (1998; 2000; 2001) along the French Guiana slope (Central Atlantic), next to the northern Brazilian coast, revealed mean catch rates ranging from 3.7 to 10 kg.h⁻¹ of *A. edwardsiana* and 0.4 kg.h⁻¹ of *A. antillensis*. Yields obtained for *A. edwardsiana* along Portugal are, however, much lower than in Guiana and Brazil, as maximum reported values attained less than 2.0 kg.h⁻¹ (Figueiredo *et al.*, 2001).

Beside the catch rate similarities, deep-sea shrimp fisheries described in both Brazil and French Guiana (Guéguen, 2000), have been characterized (a)

by a strong predominance of *A. edwardsiana*, highly concentrated in the vicinity of the 700 m isobath, and (b) by the absence of *A. foliacea* as verified in a total of 84 trawls conducted during four scientific surveys off French Guiana, and also in the operations of the chartered trawler "Mar Maria", who caught exclusively *A. edwardsiana* and *A. antillensis* in northern Brazil.

The remarkably strict bathymetric distribution pattern of *A. edwardsiana*, evidenced in both central and SW Atlantic, also approximated that reported for *A. antennatus* in the Mediterranean. According to Sardà *et al.* (2003a), this species "presents a well-defined distribution pattern (...). The number of individuals (...) rose sharply from 750 to 800 m, that is, over a depth interval of around 500 m (sic), spatially equivalent to about one mile, given the bottom configuration at the study location. From 900 m shrimp abundance fell off gradually over a distance of about five or six miles down to a depth of around 1200 m, though shrimp distribution continues over a distance of several dozen miles out to the bathyal zone". Given such common feature, off Brazil, after an early exploratory period, the chartered fleet targeting deep-water shrimps concentrated fishing effort within an extremely narrow area delimited by the 700 and 750 m isobaths (Fig. 2), where maximum yields were obtained, specially for *A. edwardsiana* (Fig. 3).

Spatial and temporal segregation of sizes and sexes have been commonly reported for deep-sea shrimps, in association with complex mobility patterns (Sardà & Cartes, 1993; Sardà *et al.*, 1997; Figueiredo *et al.*, 2001; Sardà *et al.*, 2003a; 2003b; Tudela *et al.*, 2003; Politou *et al.*, 2004; Sardà *et al.*, 2004a) and highly seasonal reproductive events (Figueiredo *et al.*, 2001; Sardà *et al.*, 2003a). In some cases, this seasonality defines the formation of vulnerable reproductive concentrations which generate catch temporal fluctuations. According to Sardà *et al.* (2003a) reproductive aggregations of *A. antennatus* are well defined in NW Mediterranean, from late winter to early summer, at 400 – 900 m depths. Fishing effort concentrates during these periods as (a) shrimps aggregate on accessible areas, (b) large females predominate contributing for a biomass peak and (c) marketability is highest. Population biology patterns of deep-sea shrimps exploited off Brazil are still unknown. Nevertheless, temporal oscillations exhibited by *A. edwardsiana* catch rate series in SE Brazil suggest, again in accordance with patterns described for *A. antennatus*, a seasonal catch regime with a winter – spring peak. The association of such regime with a likely annual reproductive cycle (as detected for *A. edwardsiana* by Guéguen, 1998 in French Guyana) is hypothetical at the moment but is to be evaluated soon as commercial catches have been continuously sampled for biological parameters.

In the Mediterranean, *A. foliacea* and *A. antennatus* fisheries have been sustained by large individuals which are priced 3-4 times the smaller ones. These fisheries have also been regarded as monospecific since no other economically important species is caught incidentally (Ragonese *et al.*, 2001). In NW Australia, on the other hand, *A. foliacea* is caught along with the astacid *Metanephrops* sp. and other five shrimp species, characterizing a multispecies activity (Wadley, 1994). In Brazil, trawlers targeting deep-sea shrimps have retained moderate catches of other valuable resources, in particular the royal-crab *Chaceon ramosae*, which has also been subject of a monospecific pot fishery, conducted in areas deeper than 500 m between 17° and 30° S. A recently implemented management plan for this fishery authorizes the operation of three vessels and an annual 600 t TAC. In addition, unauthorized vessels are allowed to land royal-crab catches not exceeding 5% of the trip total landing, a fraction defined prior to the development of the deep-sea trawl fishing and mostly concerned with abundant incidental catches produced by another developing deep-water fishery directed towards the monkfish *Lophius gastrophysus* using gillnets (Perez & Wahrlich, 2005).

In 2004, the incidental catches of crabs retained by deep-sea shrimp-trawlers attained 20.2 t, 3.3 % of the annual TAC. While this value is not significant, it is important to consider that for at least half of the referred period only one trawler operated off SE Brazil. An increasing impact on *Chaceon* spp. is expected in future years as a result of the continuous fishing effort exerted by a larger fleet. In the short run, it will be possible to predict that this impact may affect all three fisheries (deep-sea shrimps, royal crab and monkfish) management plans and challenge their need to address their economic equilibrium and biological sustainability of *C. ramosae* stock.

The trawling fishery for deep-sea shrimps in Brazil has not been subject to management actions hitherto as it has been regarded by the Brazilian fishing authorities as exploratory. Nevertheless, as the fleet rapidly increased and concentrated in localized profitable areas of the southeastern coast, a major concern has arisen regarding uncertain impacts on undimensioned but highly susceptible to fishing mortality deep-water stocks and respective habitats (Hastie, 1995; Roberts, 2002; Large *et al.*, 2003; Sardà *et al.*, 2004b; Politou *et al.*, 2004). In that sense, precautionary recommendations have been addressed to fishing authorities prioritizing (a) an immediate interruption of the entry of new vessels in the fishery and (b) a rotating harvest strategy, in order to obligate effort to be spread along the Brazilian EEZ. As operations continue to be intensively monitored by observers and VMS, enough fishing, biological and ecological parameters are expected to be made

available in the near future so as to promote upcoming management actions towards the sustainability of another emerging deep-water fishery in Brazil.

ACKNOWLEDGEMENTS

The authors are indebted to all members of the Chartered Fleet Observers Program and the Chartered Fleet Tracking Program for their hard work and the quality of collected data. We also thank vessel owners, captains and crew members of all monitored vessels for the support and good will during the long fishing trips. The Department of Fishery and Aquaculture, Ministry of Agriculture and Special Secretary of Aquaculture and Fisheries (Brazilian Government) provided funds for this study through a series of scientific cooperation programs with "Universidade do Vale do Itajaí" (MA/SARC/03/2000; MAPA/SARC/DPA/03/2001; MAPA/SARC/DENACOOP/176/2002; SEAP/PR/001/2003; SEAP/PR/078/2004; SEAP/PR/064/2005).

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(Manuscript received 03 October 2005; revised 16 January 2005; accepted 28 March 2006)