Chartered Trawling on the Brazilian Slope

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Introduction

Large-scale trawl fishing development around the world has been principally associated with the occupation of productive continental shelf areas (<200 m). The continental slope (200–2,000 m) has been less accessible to trawl fishing owing to the steep and often irregular topography and the generally discrete distribution patterns of targeted fish and shellfish within this area (Gordon et al., 1995; Merret and Haedrich, 1997). In the North Atlantic, although slope trawling was already practiced by Soviet and German vessels by the 1970's, the activity increased nearly 10 years later as the abundance of most shelf resources were greatly reduced and their catch was restricted by intensive regulation (Troyanovsky and Lisovsky, 1995; Gordon, 2001; Gordon et al., 2003). Essential to the process was the identification of profitable deep-water targets, the development of technology to overcome market limitations, and the progressive availability of charts depicting flatter grounds suitable for safe trawling (Gordon et al., 1995; Piñeiro et al., 2001). Led by French trawlers during the 1990's, a multispecies deep-water fishery was well established in areas 800–1,600 m deep mostly in the northeast Atlantic (Charuau et al., 1995; Iglesias and Paz, 1995; Gordon, 2001; Piñeiro et al., 2001; Lorance and Dupoy, 2001). In the tropical southwest Atlantic, however, another decade would go by before any effective commercial deep-water trawling activity was documented.

The continental shelf off Brazil encompasses 911,000 km² bathed mostly by southwest Atlantic waters. Its width varies along the nearly 8,000 km length of the country's coastline being particularly broad at the northern, southeastern, and southern sectors (Rossi-Wongstchowski et al., 2006). In all these sectors, trawling regimes have been established since the 1960's, basically supported by productive shelf stocks like penaeid shrimps, *Farfantepenaeus* spp., and demersal sciaenids (Haimovici et al., 2006a). For nearly 40 years these regimes were confined to the 100 m isobath (Perez et al., 2001), except for scientific surveys that, during this period, mapped slope areas and revealed a few potential resources of uncertain productivity and profitability (Haimovici, 2007).

The interest on occupying deeper waters only arose as a pattern in the national fishing industry when regional trawl fleets, particularly of the southern and southeastern coasts, began to experience economic losses due to overfishing of their main targets and were forced to look for alternatives (Perez et al., 2001). By the late 1990's, a significant number of shrimp and fish trawlers had conducted commercial operations at the shelf break, 100–200 m deep, exploiting profitable multispecies concentrations of pink cusk-eel, *Genypterus brasiliensis*; flounders, *Paralichthys* spp.; skates, family Rajidae; shrimps, *Plesionika longirostris*, and lobsters, *Metanephrops rubellus* (Perez and Pezzuto, 2006). A few years later, these same vessels

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ABSTRACT—Commercial trawling on the Atlantic slope areas off Brazil intensified in the late 1990's owing to the expansion of coastal trawling areas and the operations of a chartered foreign fleet. Between 2000 and 2003, 59 fishing trips conducted by 10 chartered trawlers were intensely monitored by observers and satellite vessel monitoring systems, totaling 9,069 tows and 30,085.2 trawling hours. Fishing operations occurred in northern, northeastern, southeastern, and southern sectors of the Brazilian coast in 60–1,173 m depths. Total retained and processed catch were 8,074.6 t and 6,479.8 t, respectively. Argentine hake, Merluccius hubbsi*; and Argentine shortfin squid,* Illex argentinus*, were the primary species taken contributing to 41.1% and 28.6% of the overall catch, respectively. The silver John dory,* Zenopsis conchifera*; monkfish,* Lophius gastrophysus*; Brazilian codling,* Urophycis mystacea*; and the black grouper,* Epinephelus nigritus*, composed 23% of total processed catch, and the remaining 7.2% was composed of deep-sea shrimps (family Aristeidae) and other teleosts and elasmobranches. The occupation of slope areas included an early exploratory phase, followed by directed phases of the upper slope (300–500 m), aiming principally at the Argentine hake, and the lower slope (>700 m), targeting valuable concentrations of deep-sea aristeid shrimps. The role of chartering for slope trawling development was critically addressed. We conclude that chartered vessels were efficient explorers and were particularly important in areas not available to the technologically limited national fleet. Because the charters were market-oriented and had elevated profit demands, however, those vessels quickly turned from exploration to exploitation and competed with national trawlers in shallower areas and produced significant impacts on Brazil's modest deep-sea resources.*

Table 1.—Summary of fishing trips conducted by chartered trawlers in Brazilian waters between October 2000 and October 2003.

Vessel	Beginning of operations	End of operations	Latitude range	Longitude range	Depth range (m)	Number of trips	Number of tows	Trawled hours	Processed production by trip (min–max)	Total processed production (t)
Joana	10/26/00	01/22/01	23°38′S–34°02′S	41°53′W–51°35′W	131–460	2	300	1,132.3	118.1–141.7	259.8
Insung 207	05/23/01	07/25/03	03°15′S–34°36′S	40°02′W–54°29′W	75–720	14	2,559	5,707.9	83.9–421.3	3,955.5
Rio Bouzos Uno	10/22/01	06/27/02	23°26′S–27°11′S	41°10′W–47°03′W	118–468	5	708	2,111.8	73.6–81.8	380.5
Cipi	10/04/01	02/13/02	23°23′S–33°05′S	41°04′W–50°28′W	224–492	3	437	1,326.7	79.1–98.3	272.7
Nuevo Apenino	09/17/01	07/30/02	23°00′S–32°50′S	41°01′W–50°23′W	124–795	9	932	3,474.3	32.4–80.5	528.2
Hermanos Vaqueros	11/13/01	06/13/02	23°08′S–28°05′S	40°10′W–48°58′W	190–1,173	5	510	2,244.5	37.4–63.1	204.2
Emanguluko	12/13/01	04/01/02	19°51′S–33°05′S	38°02′W–50°28′W	60–920	3	244	452.4	39.0–81.4	168.3
Arneles	01/23/02	01/11/02	24°01′S–31°28′S	43°06′W–49°46′W	129–394	1	18	70.7	7.7	7.7
Costa Grande	04/03/02	07/31/03	23°05′S–27°08′S	41°12′W–46°52′W	220–762	10	1,742	7,173.5	11.5–63.9	361.1
Mar Maria	08/22/02	10/20/03	08°14′N–27°38′S	34°25′W–50°31′W	203–1,158	7	1,619	6,391.1	12.7–92.2	341.8
Total/range			08°14′N–34°36′S	34°25′W–54°29′W	60–1,173	59	9,069	30,085.2	7.7–421.3	6,479.8

trawled to 200–400 m depths of the slope, first targeting monkfish, *Lophius gastrophysus*, concentrations and later including Brazilian codling, *Urophycis mystacea*; Argentine hake, *Merluccius hubbsi*; and Argentine shortfin squid, *Illex agentinus* (Perez et al., 2002a; Perez and Pezzuto, 2006).

As the regional Brazilian fleets were gradually occupying slope grounds, they were joined by foreign trawlers chartered by national companies as part of a deep-water fishing development program promoted by Brazilian authorities (Perez et al., 2003). These vessels were authorized to operate within the Brazilian Exclusive Economic Zone (EEZ), off the 200 m isobath, and were fully monitored by observers and satellite vessel monitoring system (VMS) in accordance with government regulations.

In essence, these regulations were regarded as instruments to a) promote the desired deep-sea fishing and processing technology transfer and b) assemble general knowledge on new fishing areas, potential deep-water resources, and international markets. Applied to trawlers and other deep-water vessels (i.e. gillneters and potters directed at monkfish and deep-water crabs, *Chaceon* spp., respectively) these instruments constituted the main data source to be utilized by deep-water stock assessments and management plans conducted from 2001 onward (Perez et al., 2002b; 2005; Pezzuto et al, 2006a). Despite the well-defined and mostly industry-oriented objectives, the chartering of vessels for deep-water fishing in Brazil also generated a great concern about potential impacts on untouched stocks and deep-sea ecosystems as well as uncertainties about its sustainability. These concerns were even more critical in light of the conflicting demands of a large and highly overcapitalized national fleet.

This paper describes the slope trawling fishery conducted by chartered vessels off Brazil between 2000 and 2003, including the physical characteristics of vessels and gears, the definition of main targets, the strategies of fishing ground occupation, and spatial and temporal patterns of catch, effort, and catch rates. Along with a previous assessment on the slope-trawling fishery conducted by national vessels (Perez and Pezzuto, 2006), this review is intended to improve our understanding of the status and perspectives of this new deep-water fishing era in Brazil and to critically address the costs and benefits of the chartering policies in such a process.

Data Sources and Analyses

Analyzed data is from the Chartered Fleet Observers Program developed by Universidade do Vale do Itajaí as part of a scientific cooperation project with Brazilian fishing authorities (Ministry of Agriculture and Special Secretariat for Aquaculture and Fishery). All 59 fishing trips conducted by 10 chartered trawlers between 26 October 2000 and 20 October 2003 (Table 1) were monitored by observers assigned to collect, after each tow, information on fishing areas (position and depth), effort (tow duration), and catch composition. All retained species were identified on board and also on land, through collected specimens and photographic/videographic material. Catches were recorded in "processed weight" and later transformed into "live weight" using conversion indices for each species, as defined by the vessel's crew and/or experimentally by the observers aboard. Catch rates were expressed in kg per trip and kg per hour.

The main targets of chartered trawlers off Brazil were assessed using the method proposed by Biseau (1988). This method quantified, initially, the proportion taken by each species in the total biomass retained by each tow ($c_{i,s}$) as follows:

$$c_{i,s} = \frac{T_{i,s}}{T_i} \cdot 100 \qquad (1)$$

where $T_{i,s}$ is the total biomass of species s in the tow i and T_i is the total biomass obtained by tow i. $c_{i,s}$ is then pooled by truncated classes of 1 to 100%, each one denominated Level of Qualification (LQ), and, for each j^{eth} LQ, the sum of the total biomass is calculated for each species s ($TC_{j,s}$). Finally the following equation

$$P_{j,s} = \frac{TC_{j,s}}{T_s} \cdot 100 \qquad (2)$$

where T_s is the total landed biomass of species s, calculates the relative contribution (in percentage) of each LQ to the total catch of species s in one fishing trip ($P_{j,s}$). These contributions are presented in a cumulative frequency distribution whose form allows an assessment of the level of directionality of each tow to the retained species (Biseau, 1988).

Catch, effort, catch rates, and fishing targets were analyzed by vessel. Tows conducted in the southeastern and southern sectors of Brazilian coast were also grouped by latitudinal strata (North, north of lat. 25ºS; Center, between lat. 25º and 29ºS; South, south of lat. 29ºS); depth strata (<200 m; 200–399

Table 2.—Summary of chartered trawlers that operated off Brazil from October 2000 to October 2003 including their flag country and their main features.

Vessel	Flag country	Year of construction	Total length (m)	Engine power (hp)	GT (t)	Storing capacity (t)	Autonomy (days-at-sea)	Crew (workers)
Joana	Portugal		60.0	1,700	890	320	70	32
Insung 207	South Korea	1975	56.9	2,200	925	350	50	41
Rio Bouzos Uno	Spain	1986	33.0	1,200	324	80	80	18
Cipi	Spain	1973	39.0	870	270	110	70	19
Nuevo Apenino	Spain	1998	33.0	1,000	200	145	60	18
Hermanos Vaqueros	Spain	1969	27.8	490	168	75	50	18
Emanguluko	Namibia	1989	31.1	1,900	483	100	24	28
Arneles	Spain	1984	75.7	1,850	789	692	120	30
Costa Grande	Spain	1973	30.0	800	170	80	50	16
Mar Maria	Spain	1998	38.4	1,200	271	140	80	20

m; 400–599 m; >600 m); trimesters (I: Jan.–Mar.; II: Apr.– June.; III: July–Sept.; IV: Oct.–Dec.), and years (2000, 2001, 2002, and 2003).

The Fleet

The chartered trawlers operating off Brazil from October 2000 to October 2003 originated from Spain (7), Portugal (1), Republic of South Korea (1), and Namibia (1). These vessels are described in Table 2. Three vessels (*Joana, Insung 207,* and *Arneles*) were noticeably larger (57–76 m long), with powerful engines (1,700–2,200 hp), and able to carry 30–41 men crew and to store 320–692 t of frozen fish. The remaining seven vessels were less robust, running 28–39 m long, 490–1,200 hp engines, 16–20 men crew, and store 75–145 t of frozen fish. Except for the trawler *Arneles* that could operate continuously for 120 days at sea, the chartered trawlers autonomy ranged between 24 and 80 days. All chartered trawlers operating in Brazil were built between 1969 and 1998, being 3–32 years old in 2001.

Table 3.—Physical features of the fishing gear used by chartered trawlers off Brazil from October 2000 to October 2003.

Vessel	Head rope length (m)	Ground rope length (m)	Use of bobbins	Trawl vertical opening (m)	Mesh size at cod end (mm)	Door weight (kg)
Joana	37.0–56.0	18–70	Frequent	3.5–4.5	135	1,250
Insung 207	40.0–90.0	55–100	Frequent	3.5–7.0	70–110	1,600–2,500
Rio Bouzos Uno	58.0–65.0	60–80	Frequent	3.0	65–70	750–800
Cipi	58.5–67.2	70–80	Occasional	10.0–15.0	60–85	620
Nuevo Apenino	33.0–85.0	45–100	Occasional	2.0–5.0	50–90	900–1,000
Hermanos Vaqueros	65.4–67.0	80		3.0–10.0	70	500
Emanguluko	38.0–80.0	62–95	Frequent	2.0–5.0	70–120	1,600
Arneles	92.0	110	Frequent	4.0	100	1,600
Costa Grande	45.0–101.0	47–120		1.0–2.5	50–80	500–650
Mar Maria	40.0–71.0	41–85	Occasional	2.2–3.0	80	900

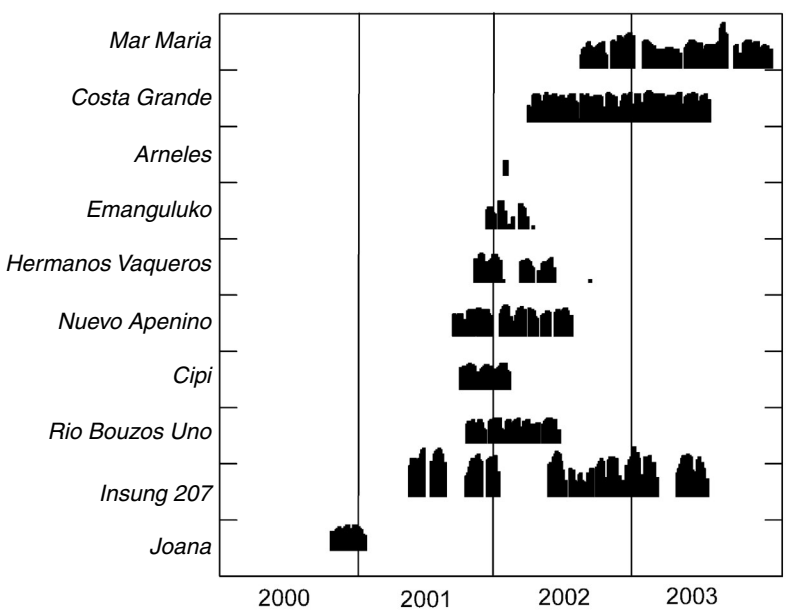


Figure 1.—Temporal distribution of trawls conducted by chartered vessels on slope areas off Brazil from 2000 to 2003. Bar heights are proportional to the number of tows conducted during each day.

Two Spanish vessels (*Cipi* and *Hermanos Vaqueros*) were side trawlers, whereas all the others were stern trawlers. Side trawlers and stern trawlers were single- and double-decked, respectively. In the latter, the lower deck was sheltered and used for catch processing. Various trawl nets were used. Head rope and ground rope dimension ranges were 33–101 m and 41–120 m, respectively (Table 3). Mesh was made of braided or twisted polyethylene and measured 50–120 mm at the cod-end (stretched mesh). These nets were towed at 2.3–3.5 knots and their estimated vertical opening ranged from 3 to 15 m. Doors used weighed between 500 and 2,500 kg. On rough grounds, some trawlers used steel or rubber bobbins at the ground ropes (200–500 mm in diameter). Chains could replace these bobbins when fishing was conducted over smooth, soft ground.

Fishing Dynamics

Chartered trawlers conducted 59 fishing trips between 2000 and 2003

(Fig. 1) totaling 9,069 tows and 30,085.2 trawling hours (Table 1). Fishing operations occurred in northern, northeastern, southeastern, and southern sectors of Brazilian coast in areas 60 to 1,173 m deep (Fig. 2, 3).

In the southeastern and southern coast, nearly 70% of the tows conducted by the chartered trawlers were between lat. 23°S and lat. 25°S, whereas a secondary fishing area was between lat. 26°S and lat. 29°S (Fig. 3A). Similarly 60% of the total tows were conducted on 300–500 m deep grounds and a secondary depth was at 700–800 m isobaths for 20% of the tows (Fig. 3B). Occupation of the southern and southeastern slope areas resulted in the establishment of three main fishing grounds characterized by concentrations of the most abundant and/or valuable species: Argentine hake, Argentine shortfin squid, and the deep-sea shrimps (family Aristeidae). This process occurred in three consecutive phases: Exploratory, Directed (upper slope), and Directed (lower slope).

Exploratory phase: Established between late 2000 and mid 2001, this phase included the first operations of the trawlers *Joana* and *Insung 207*, which conducted tows along the entire southeastern–southern Brazilian coast between 100–400 m depths (Fig. 3A, 3B). In early 2001, the trawler *Joana* abandoned the Brazilian waters (Fig. 1).

Directed phase of the upper slope: From late 2001 onward, this phase was characterized by the intense exploitation of the two main latitudinal strata, lat. 23°S–25°S and lat. 26°S–29°S, between the 250 and 450 m isobaths (Fig. 3A, 3B). The trawler *Insung 207* which initiated this second phase was joined later by six trawlers, mostly Spanish. Operations directed to the northern and southern latitudinal strata were associated with commercial concentrations of the Argentine hake and the Argentine shortfin squid, respectively. Except for *Insung 207*, all vessels cited above terminated their operations off Brazil during 2002 (Fig. 1).

Directed phase of the lower slope: Initiated in early 2002, this phase was directed at concentrations of deep-sea

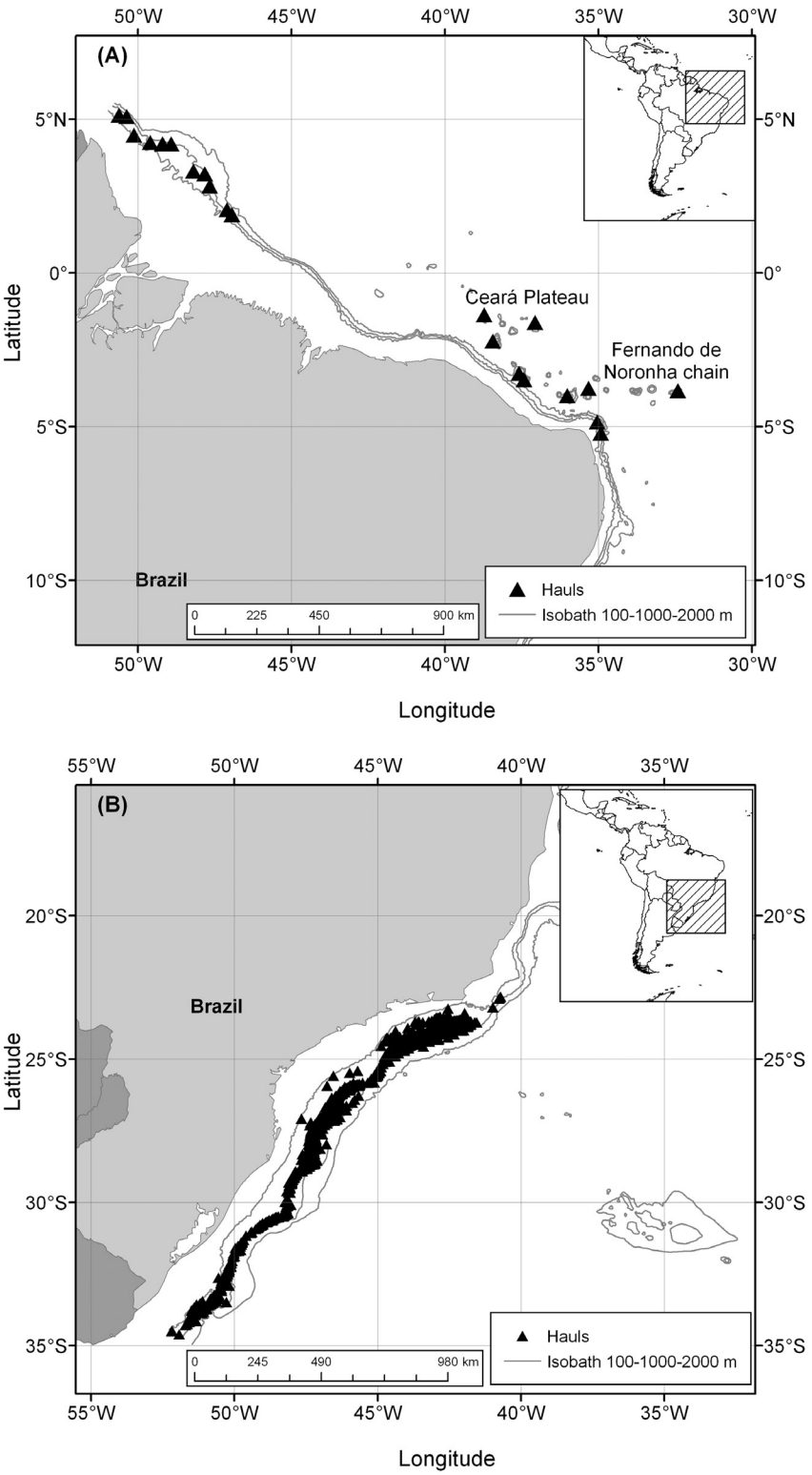


Figure 2.—Spatial distribution of trawls conducted by chartered vessels on slope areas off Brazil from 2000 to 2003. (A) Northern and Northeastern sectors and (B) Southeastern and Southern sectors of Brazilian EEZ.

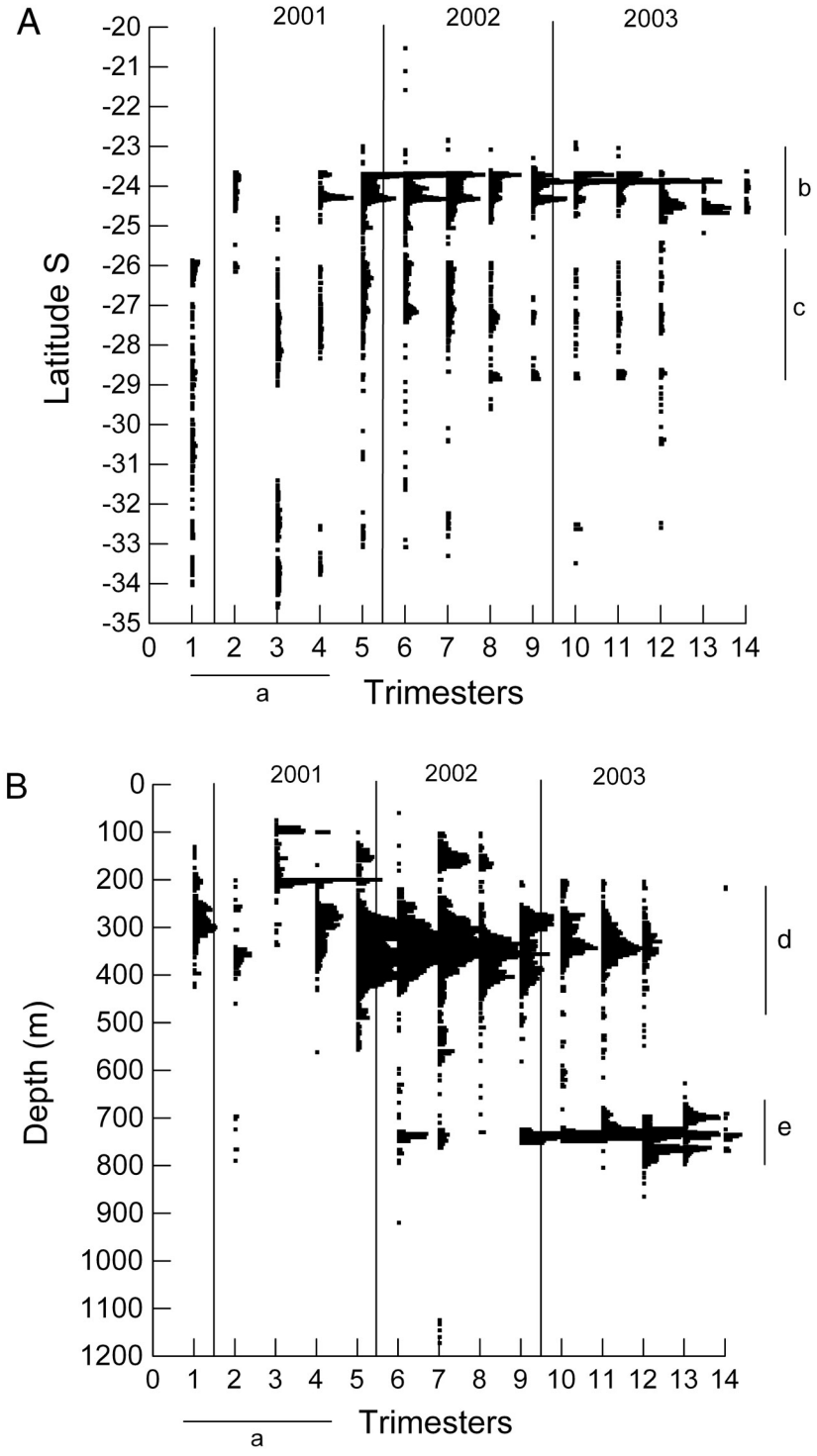


Figure 3.—Latitudinal (A) and depth (B) distribution of trawls conducted by chartered vessels on slope areas off Brazil in 14 trimesters from 2000 to 2003. a. Exploratory phase; b. Directed phase of the upper slope (Argentine hake) and directed phase of the lower slope (aristeid shrimps); c. Directed phase of the upper slope (Argentine shortfin squid); d. Directed phase of the upper slope (Argentine hake and Argentine shortfin squid); e. Directed phase of the lower slope (aristeid shrimps).

shrimps. In 2002 the trawler *Nuevo Apenino* conducted exploratory tows deeper than 700 m obtaining, north of lat. 25°S, the first commercial catches of the "carabinero" or scarlet shrimp, *Aristaeopsis edwardsiana*. By late 2002 two other trawlers initiated the directed exploitation of this species as well as the "moruno" or giant red shrimp, *Aristaeomorpha foliacea*, and "alistado" shrimp, *Aristeus antillensis*, between lat. 24°S and lat. 25°S and the 700–800 m isobaths (Fig. 3A, 3B). After 2002 this fishery expanded with the entry of new chartered vessels and the identification of new fishing grounds north of lat. 19°S (Pezzuto et al., 2006b).

The trawlers *Mar Maria* and *Insung 207* also operated in the northern and northeastern sectors of Brazilian coast. These operations were distributed on a wide longitudinal range concentrating within long. 35°W and long. 38°W (Fig. 2A). Nearly 100 tows were conducted close to the northern boundary of the Brazilian EEZ (long. 48°W–51°W) on depths from 400 to 1,200 m, where moderate catches of deep-sea shrimp were obtained. Operations of *Mar Maria* also concentrated on the flat tops of seamounts that compose the Ceará Plateau and the Fernando de Noronha Chain (Fig. 2A). These seamounts elevate from nearly 1,000 m depths, at their base, to 200 m depths at the top, where the gentle topography was found to be suitable for trawling. Catches in these areas were mostly composed of the black grouper, *Epinephelus nigritus*, whose catch rates decreased rapidly to unprofitable levels forcing this trawler to move to southern Brazil and join the deep-sea shrimp fishery.

Catches and Targets

The chartered trawlers produced altogether 8,075 t of retained catch and 6,480 t of processed products destined for international markets (Table 1, 4). Nearly 70% of the total retained catch was composed of the Argentine hake (41.1%) and the Argentine shortfin squid (28.6%) (Table 4). The bone fishes silver John dory, monkfish, Brazilian codling, and black grouper composed together 23% of the total retained catch.

Table 4.—Catch in tons (t) retained by the chartered trawlers off Brazil from October 2000 to October 2003. Numbers in parentheses represent percentages of the total retained catch of each vessel. Argentine shortfin squid, *Illex argentinus*; Argentine hake, *Merluccius hubbsi*; silver John dory, *Zenopsis conchifera*; monkfish, *Lophius gastrophysus*; Brazilian codling, *Urophycis mystacea*; black grouper, *Epinephelus nigritus*; deep-sea shrimps, family Aristeidae; and other bony and cartilaginous fish.

Vessel	Argentine shortfin squid	Argentine hake	Silver John dory	Monkfish	Brazilian codling	Black grouper	Deep-sea shrimp	Others	Total
Joana	56.9	47.5	124.9	19.1	3.7	0.0	0.0	17.6	269.7
	(21.1)	(17.6)	(46.3)	(7.1)	(1.4)	(0.0)	(0.0)	(6.5)	
Insung 207	1,830.7	1,657.9	420.1	178.5	33.5	0.0	0.0	329.5	4,450.2
	(41.1)	(37.3)	(9.4)	(4.0)	(0.8)	(0.0)	(0.0)	(7.4)	
Rio Bouzos Uno	83.9	348.5	13.7	19.0	37.1	0.0	0.0	22.1	524.3
	(16.0)	(66.5)	(2.6)	(3.6)	(7.1)	(0.0)	(0.0)	(4.2)	
Cipi	41.6	270.6	27.7	30.6	16.9	0.0	0.0	6.6	394.0
	(10.6)	(68.7)	(7.0)	(7.8)	(4.3)	(0.0)	(0.0)	(1.7)	
Nuevo Apenino	74.8	498.0	36.8	39.5	39.2	0.0	0.6	42.2	731.1
	(10.2)	(68.1)	(5.0)	(5.4)	(5.4)	(0.0)	(0.1)	(5.8)	
Hermanos Vaqueros	13.3	187.1	1.9	61.5	27.7	0.0	0.0	19.9	311.4
	(4.3)	(60.1)	(0.6)	(19.8)	(8.9)	(0.0)	(0.0)	(6.4)	
Emanguluko	118.1	61.0	37.1	31.4	3.6	0.0	0.0	3.8	255.0
	(46.3)	(23.9)	(14.5)	(12.3)	(1.4)	(0.0)	(0.0)	(1.5)	
Arneles	1.6	7.3	0.6	0.2	0.0	0.0	0.0	1.0	10.7
	(14.8)	(68.8)	(5.4)	(1.8)	(0.0)	(0.0)	(0.0)	(9.2)	
Costa Grande	86.0	241.3	11.8	327.7	13.6	0.0	41.4	45.5	767.3
	(11.2)	(31.4)	(1.5)	(42.7)	(1.8)	(0.0)	(5.4)	(5.9)	
Mar Maria	5.4	3.1	0.0	4.5	1.1	293.1	34.2	19.6	361.0
	(1.5)	(0.9)	(0.0)	(1.2)	(0.3)	(81.2)	(9.5)	(5.4)	
Total	2,312.3	3,322.3	674.6	712.0	176.4	293.1	76.2	507.8	8,074.6
	(28.6)	(41.1)	(8.4)	(8.8)	(2.2)	(3.6)	(0.9)	(6.3)	

Deep-sea shrimps (family Aristeidae) and other bony and cartilaginous fish composed the remaining 7.2%.

Annual production peaked at 5,000 t in 2002 when nine trawlers were operating simultaneously in Brazilian waters (Fig. 4A). The bulk of this production was composed of massive catches of Argentine hake and Argentine shortfin squid (Fig. 4B). The trawler *Insung 207* produced the largest overall catch. This trawler not only conducted the greatest number of trips during the study period but also obtained, in 2002, the largest Argentine shortfin squid catch ever recorded in Brazilian waters (1,241 t in three fishing trips in July–September 2002). In all the other years the Argentine hake was the most abundant species in the catch (Fig. 4B).

The main catch components during the study period were principally caught in the area delimited by lat. 23°S and lat. 25°S (Fig. 5A). An exception was the Argentine shortfin squid whose catches concentrated further south between lat. 26°S and lat. 30°S. Also it is worth noting that the Brazilian codling was the only retained species caught throughout the entire latitudinal range whereas the deep-sea shrimps were restricted to northernmost areas (Fig. 5A). Chartered fleet operations also obtained most of their catch in the 300–500 m depth stratum with the exception of the deep-sea shrimps that were caught in depths of 700 m on average (Fig. 5B). All species were caught throughout the 24-h period, but the Argentine shortfin squid and the Argentine hake were mostly caught during daytime whereas catches of the silver John dory and the monkfish tended to be larger between 1200 h and 2400 h (Fig. 5C).

Slope trawling off northern and northeastern Brazil had deep-sea shrimps and the black grouper as the main targets, respectively, the latter composing over 90% of retained catch. Off southeastern and southern Brazil the six most abundant components of the retained catches were initially regarded as potential targets of chartered trawlers during the studied period.

The analysis of targets in multispecies fisheries, as proposed by Biseau (1988), enabled the characterization of three types of cumulative frequency distribution curves of the catches (Fig. 6). These curves were used to define criteria for the classification of the species into three categories: incidental, target-species, and massive target species (Table 5). Following these criteria, cumulative curves built for all six species were analyzed considering all recorded tows and tows pooled by trawler, trimester, latitudinal and bathymetric strata (Table 6).

The Brazilian codling was generally classified as an incidental species (Fig. 6) for all chartered trawlers, where the species rarely contributed more than 20% of the retained catch (Table 6). The same was observed in most trimesters and in latitudinal and bathymetric strata. Exceptions to this pattern were found in tows south of lat. 29°S and during the end of 2000, when the species may have

Table 5.—Criteria for classification of the species caught by the chartered trawlers fleet operating off Brazil into target categories adapted from Biseau (1988).

Species	Definition	Criteria
Incidental	Species not subject to directed effort but retained due to its commercial value	More that 40% of the species total retained biomass originated from tows where the species represented less than 20% (QL) of the retained biomass
Target species	Species subject to directed effort	Between 30 and 60% of the species total retained biomass originated from tows where the species represented more than 40% (QL) of the retained biomass
Massive target species	Species subject to directed effort whose distribution is extremely gregarious and that are caught in large quantities without abundant bycatch	More than 60% of the species total retained biomass originated from tows where the species represented more than 40% (QL) of the retained biomass

been included in the role of the targets during the trawling exploratory phase (Table 6).

The monkfish was classified as a target species in general terms but such classification was not homogeneous among trawlers (Fig. 6, Table 6). Furthermore the species was incidental during most of the analyzed period, but during the second trimesters of 2001, 2002, and 2003 it oscillated between target species and massive target species. The same was observed in areas deeper than 600 m (Table 6).

The Argentine shortfin squid, the Argentine hake, the silver John dory and the deep-sea shrimps (here analyzed as one single category) were classified as massive target species which means that they constituted targets of highly directed effort and/or occurred in such dense mono-specific concentrations in nature as to contribute to the largest part of the catch obtained by each tow (Fig. 6). In all species, however, that classification was not homogeneous among trawlers (Table 6). Furthermore, the exploitation of the Argentine hake and the Argentine shortfin squid as massive targets was restricted to the period between late 2001 and early 2003, in the former species, and to the winter seasons, south of lat. 25°S and between 200–600 m depths in the latter species (Table 6). The silver John dory was classified as a massive target species in several fishing seasons, all latitudinal strata, and in areas shallower than 400 m (Table 6).

Deep-sea shrimps were a target species in the tows conducted by the trawler *Nuevo Apenino* who produced the first commercial catches of these species off southeastern Brazil. The trawlers *Costa Grande* and *Mar Maria*, on the other hand, directed their operations to these shrimps where they were classified as a massive target species (Table 6). Such conditions were observed from late 2002 onwards, as these vessels initiated their operations in Brazilian waters, north of lat. 25°S and deeper than 600 m (Table 6).

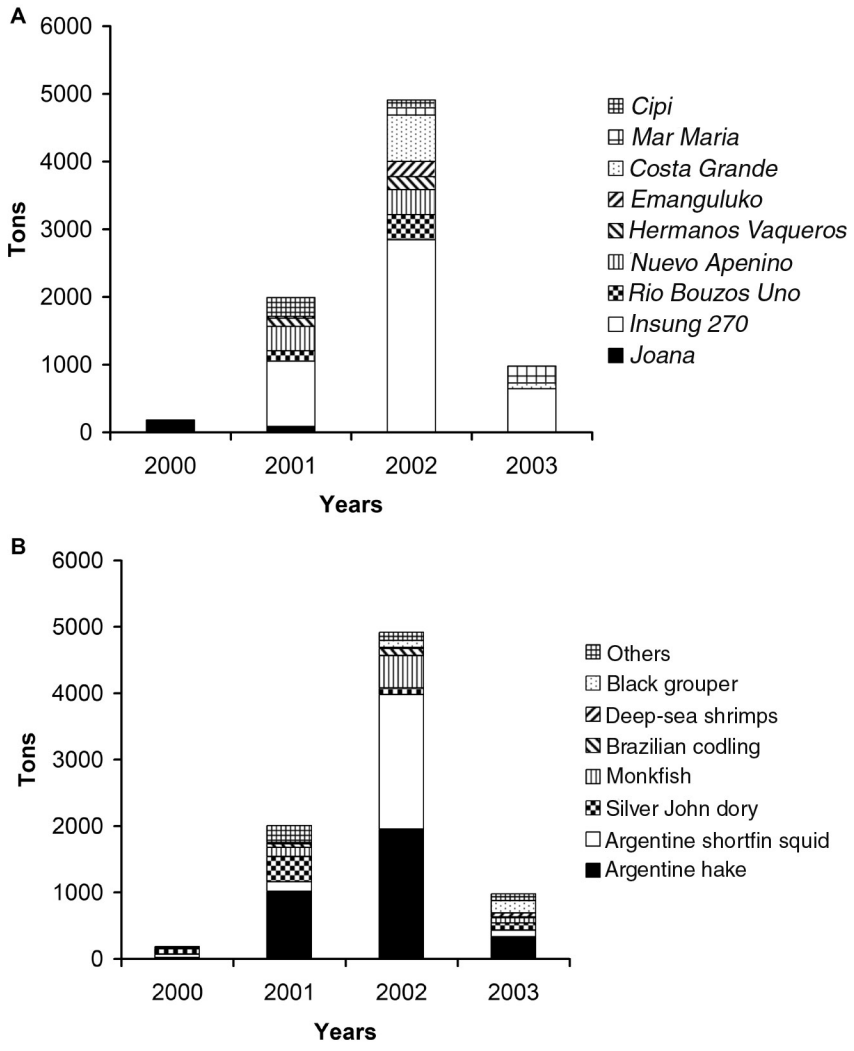


Figure 4.—Total retained catches reported by chartered trawlers off Brazil between 2000 and 2003 classified by vessel (A) and species (B).

Catch Rates

In the southern and southeastern sectors of Brazilian coast total retained catch rates were, on average, 123,012.2 kg/trip (± 15,384.1 kg/trip SE) and 368.9 kg/h (± 11.5 kg/h SE) (Tables 7, 8). These rates increased in 2001–02 (394–489 kg/h) during the upper slope directed phase (targeting the Argentine hake and the Argentine shortfin squid) and decreased almost 60% in 2003, when the lower slope directed phase aiming at the deep-sea shrimps was established (Table 8). Mean catch rates were highest in the shallowest and southernmost strata and tended to decrease toward deep northern grounds (Fig. 7). Mean catch rates in northern and northeastern Brazil, were 39,729.6 kg/trip (± 13,033.5 kg/trip SE) and 107.2 kg/h (± 3.9 kg/h SE) (Tables 7, 8).

The Argentine hake and the Argentine shortfin squid were the most productive targets of the chartered slope trawling off Brazil reaching, on average, over 100 kg/h (Table 8). The former species was most productive in 2001 and 2002 when mean catch rates oscillated between 171.3–183.3 kg/h. In 2003 catch rates dropped sharply to nearly 30% of the previous levels. The Argentine shortfin squid, on the other hand, had one sporadic fishing episode in mid 2002 when catch rates of one particular trawler averaged nearly 200 kg/h (Table 8).

Aside from that episode, mean catch rates varied between 16 and 48 kg/h. Monkfish catch rates were also superior in 2001 and 2002, although interannual variability was not as pronounced as in the case of the Argentine hake. The silver John dory and the Brazilian codling were not permanent targets of the chartered fleet, and therefore the retained catches may not have been related with their availability on the slope fishing grounds. However, the elevated catch rates of the silver John dory between 2001 and 2003 were noticeable (Table 8). In general, all catch rates declined in 2003 except for those recorded for the deep-sea shrimps (Table 8). In essence that reflects the reduction of the chartered fleet that year and the intensification of trawling in the lower slope grounds where most of the fish and squid targets are not abundant.

The Argentine hake and Argentine shortfin squid catch rates were slightly highest at depths shallower than 200 m and tended to decrease toward deeper grounds being totally absent in areas deeper than 600 m (Fig. 7A). Latitudinally, however, both species exhibited inversed distribution patterns with Argentine hake and Argentine shortfin squid catch rates being largest in the northern and southern sectors, respectively (Fig. 7B). Whereas the monkfish catch rate distribution was relatively homogeneous in all depth and latitudinal strata, silver John dory catch was scarce in areas deeper than 400 m and in all latitudinal strata (Fig. 7). Deep-sea shrimps catch rates were only available for the lower 600 m areas of the northern sector (Fig. 7).

Discussion

Chartered trawlers operated in the Brazilian slope following patterns in many ways similar to the ones exhibited during the development of deep-water trawling in the North Atlantic, which involved both exploratory and specialized phases in association with different trawler types (Iglesias and Paz, 1995; Charuau et al., 1995; Gordon, 2001). Off Brazil, the process was pioneered in late 2000–early 2001 by two large vessels that covered broad latitudinal

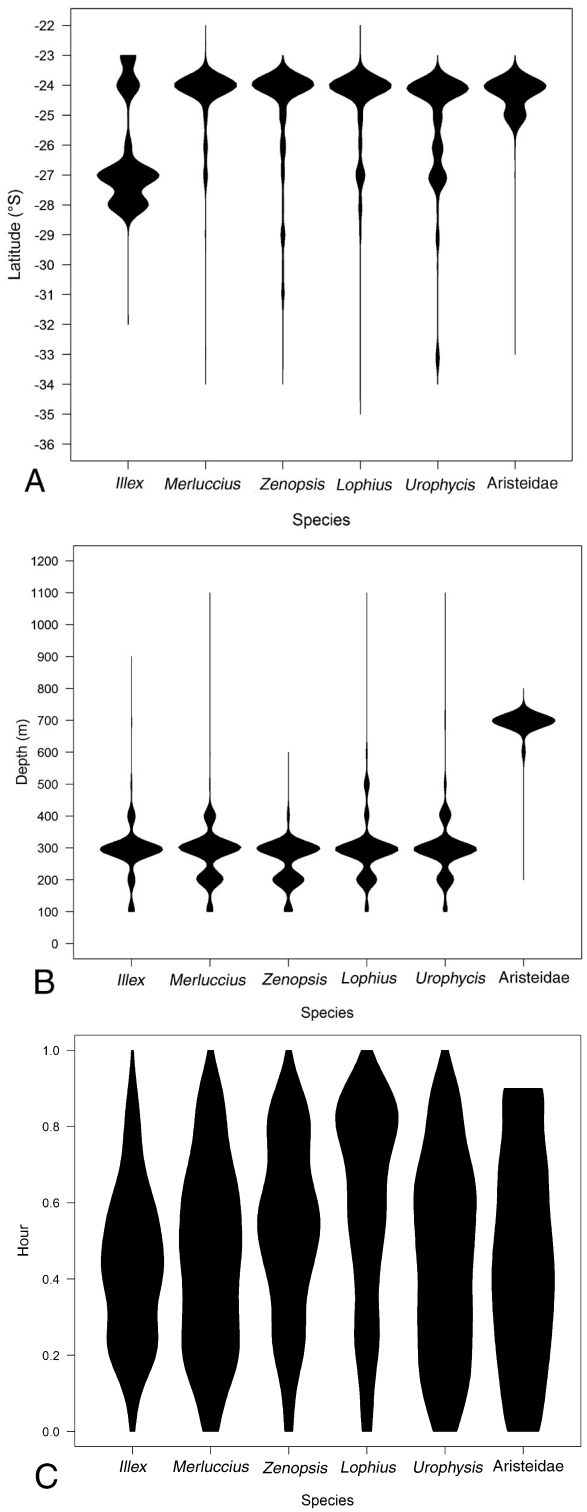


Figure 5.—Distribution of catches of Argentine shortfin squid, Argentine hake, silver John dory, monkfish, and deep-sea shrimps (family Aristeidae) off Southeastern and Southern Brazilian slope between 2000 and 2003. Area widths are proportional to the relative contribution of latitudes (A), depth (B), and decimal transformed hour of fishing (C) (e.g. 0.5 is 1200h; 0.0 is 2400h) to the total catch of each species.

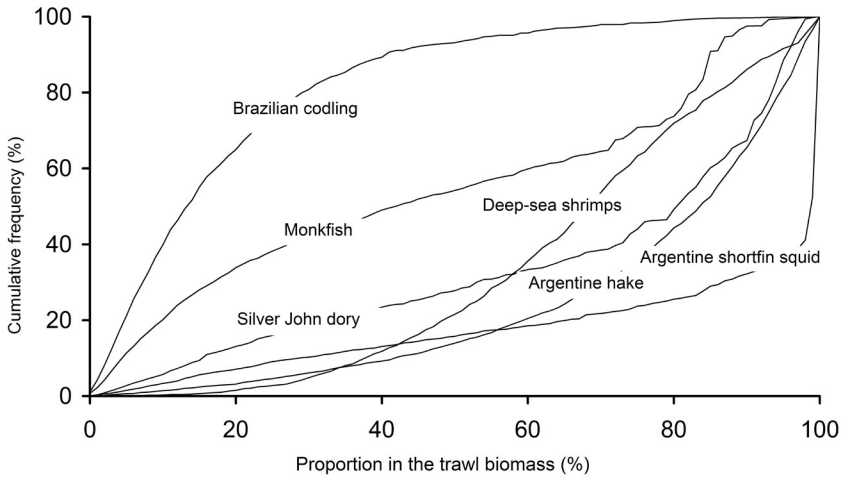


Figure 6.—Fishing target analysis of chartered trawlers on slope areas off Brazil from 2000 to 2003. Curves are cumulative frequencies of the relative contributions of the main catch components to the biomass produced by one trawl (QL).

areas and a variety of habitats. These vessels obtained some of the first profitable catches of resources previously considered as either unproductive or uneconomical, aside from delimiting their main slope fishing grounds (Perez et al., 2003; Haimovici, 2007).

This exploratory phase was shortly followed by the entry of Spanish trawlers highly focused on Argentine hake production in the southeastern sector of the Brazilian slope. Previously operating off northwest Africa, such vessels were smaller, highly efficient, and able not only to fully exploit the hake concentrations 300–400 m deep but also to occasionally explore the deep slope for new opportunities. By the end of 2002, as international markets for hake caught off Brazil became no longer favorable, most vessels abandoned Brazilian waters.

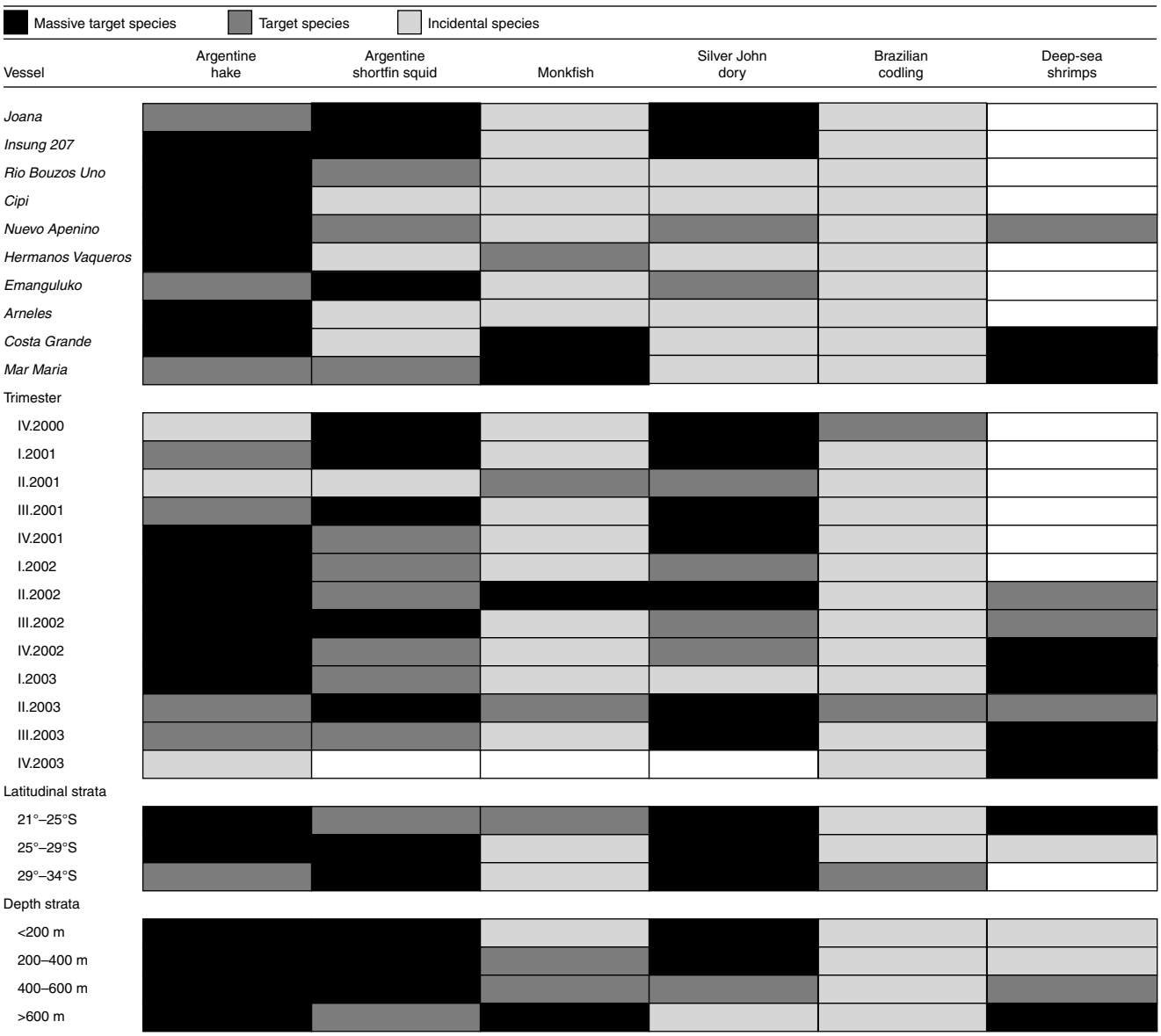
In association with the end of the directed phase, however, a) a "national" trawl fishery consolidated on the upper slope grounds off southeastern Brazil aiming at hake and other species mostly for the domestic market (Perez and Pezzuto, 2006), and b) a new phase directed towards valuable aristeid shrimps began from the subsequent operations of two remaining Spanish trawlers. This justified the continuation of the chartering program and the onset of a new lower slope trawl fishing phase (Pezzuto et al., 2006b).

In northern and northeastern Brazilian waters, chartered trawling led to less promising perspectives. First, another potential fishing ground for aristeid shrimps was detected off the northern State of Amapá, possibly associated with stocks already exploited in the French Guiana EEZ (Guéguen, 2000; Pezzuto et al., 2006b). Unlike the trawlers in the neighboring country, these grounds have not attracted the Brazilian trawl fleet that is strongly focused on the coastal pink shrimp, *Farfantepenaeus subtilis*, production (Aragão et al., 2004). As for chartered trawlers, the area was not considered a priority due to operational difficulties, as imposed by strong bottom currents and deep fine sediment layers. Secondly, the chartered fleet produced a brief and unprecedented trawl fishing episode on the flat tops of some seamounts off northeastern Brazil, which exploited to exhaustion dense concentrations of the black grouper. Both scientists and fishing authorities reaction to the analysis of this episode was to recommend the closure of these seamounts for trawl fishing and include them on the list of potential Marine Protected Areas of the Brazilian coast (Anonymous, 2006)

Brazilian slope trawling until 2003 concentrated on the so-called "permanent residents of the upper 400 m" (Gordon et al., 1995; Gordon, 2005) composed of species more closely related to shelf dwellers than true deep-sea forms (Merret and Haedrich, 1997). Off southeastern and southern Brazil, these targets were amongst the dominant species of the upper slope area (100–500 m) as shown by trawl surveys conducted in 2001–02 (Haimovici et al., 2006b). These surveys also showed the silver John dory, Argentine hake, Brazilian codling, monkfish, and Argentine shortfin squid particularly concentrated on the 300–500 m depth stratum where both chartered and national trawlers overlapped and obtained their most productive catches between 2000 and 2003 (Perez and Pezzuto, 2006). Latitudinally, catch patterns of the chartered fleet also coincided with those shown by the national trawlers and the trawl surveys including, for example, the well-known concentration of Argentine hake and the gulf hake in the northern and southern extremes of the fishing area respectively (Perez and Pezzuto, 2006; Haimovici et al., 2006b). Whereas landings composition corroborated such spatial exploration pattern, existing differences between national and chartered fleets could be related, however, to the national/international market preferences aimed by these fleets respectively (Perez et al., 2002a; Perez et al., 2003; Perez and Pezzuto, 2006). Thus the abundant gulf hake has been a major target of national but not chartered trawlers, and the silver John dory and Argentine squid has been mostly retained (and exported) by chartered vessels. These differences further implied in particular (although not yet empirically addressed) discard practices involving the above mentioned and other abundant slope species including beardfish, *Polimixia lowei*; Splendid alfonsino, *Beryx splendens; Helicolenus lahillei*; and Marini's grenadier, *Caelorinchus marinii* (Haimovici et al., 2006b).

A particular scenario emerged from the establishment of the aristeid shrimp-directed lower slope fishery. Trawling operations in this area have been highly restricted to the most productive 700–800 m depth range and produced significant catches of the deep-sea

Table 6.—Analysis of the targets of the chartered trawler fleet operating off Brazil from October 2000 to October 2003 according to criteria defined in Table 5. White areas refer to species not present in the catches.



crabs, *Chaceon ramosae* (Pezzuto et al., 2006b) as well as a high diversity of truly deep-sea fin-fish (families Synaphobranchidae, Macrouridae, Trachichthyidae, Berycidae, Astronesthidae, Oreosomatidae, Ipnopidae, Alepocephalidae, Ophidiidae and others), elasmobranches (families Rajidae, Scyliorhinidae), holocephalids (family Chimaeridae), and cephalopods (family Histioteuthidae, subfamily Bathypolipodinae).[1] Hitherto none of these bycatch species (some of them commercially exploited elsewhere) have been identified as potential fishing targets, a consequence of either the high profitability of aristeid shrimp catches or inexistent (or still undetected) specific productive grounds. Whereas the next deep-water trawling phase off the Brazilian coast is uncertain, the abundant and diverse by-catch produced by deep-water shrimp trawling, as also described for similar fisheries worldwide (Sartor et al., 2003; D'Onghia et al., 2003), may be a critical aspect to be considered for the future development of this new Brazilian fishery.

Bottom trawling is a traditional fishing practice in Brazil that has sustained a significant proportion of the country's demersal catches in the past 40 years (Haimovici et al., 2006a; Valentini and Pezzuto, 2006). This practice devel-

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oped as a large-scale industry, after the technological influence of a process of chartering and importing double-rig trawlers from the Gulf of Mexico in the mid 1960's (Valentini et al., 1991). From 2000 onwards, the chartering of foreign vessels reappeared as a mechanism to induce the expansion of such industry into deep-sea areas, a process that involves new paradigms on fishing, processing, and commercializing (Perez et al., 2001; Perez et al., 2003). Unlike the introduced bottom gillnets for monkfish fishing and pots for deep-sea crabs (Wahrlich et al., 2005; Pezzuto et al., 2006a), slope trawling could rapidly become a concrete trend of national fishing owing to the already available fleet and the lower costs involved in setting those new paradigms. In fact, southeastern and southern upper slope occupation by both national and foreign trawlers was virtually simultaneous, the latter being regarded by the former more like unfair competitors than models. The analysis of data generated extensively by observers on board chartered trawlers, however, allowed some important distinctions to be made about the factual role of chartering to the development of slope trawling off Brazil.

Chartered vessels, in comparison with national ones, were larger, powered by stronger engines and with faster winches, could spend a long time at sea and had crews experienced in operations over slope grounds elsewhere in the Atlantic. As explorers, these vessels were able to cover a vast area between the two extremes of the country's EEZ, from 100 to 1,000 m, accomplishing in 2 years more than any research vessel or national trawler had in decades. However, these vessels were market-oriented with elevated profit demands, which made them quickly turn from exploration to exploitation particularly focused on Argentine hake and aristeid shrimps concentrations in southeastern Brazil. Technologically limited, national trawlers, traditionally operating on the shelf and shelf break in that region, were able to expand to the upper slope and compete with foreign trawlers for hake but not for the valuable deep-sea shrimps on deeper areas. In the latter case fishing technology possibly justified chartering, as national trawlers could not easily assess these grounds. In the former case, however, national exploitation of Argentine hake prevailed, possibly because double-rig trawlers were more numerous, efficient, and favored by a more stable and less competitive domestic market (Perez and Pezzuto, 2006).

Another relevant aspect is concerned with the impacts the foreign trawl fleet could have made on slope resources, both individually and in addition to the ones produced by national trawlers. Recent analysis has indicated that annual Argentine hake landings

Table 7.—Total retained catch rates (kg/trip) obtained by the chartered trawl fishery on slope grounds off Brazil between 2000 and 2003. The number of trips is presented in the first row followed by the mean catch rate (± SE) and the maximum value in parentheses. SE–S, southeastern and southern sectors; N–NE, northern and northeastern sectors.

Year	SE–S	N–NE
2000	2 62,488.8 –120,877.4	
2001	16 124,039.5 ± 20,625.5 (300,980.6)	
2002	33 145,540.7 ± 25,607.3 (516,508.2)	3 38,624.8 ± 15,065.3 (55,035.0)
2003	11 70,689.2 ± 24,221.2 (257,104.2)	5 40,392.6 ± 20,180.8 (92,156.6)
Total	62 123,012.2 ± 15,384.1 (516,508.2)	8 39,729.6 ± 13,033.5 (92,156.6)

Table 8.—Total retained catch rates (kg/h) of the main fishing targets obtained by the chartered trawl fishery on slope grounds off Southeastern–Southern and Northeastern–Northern Brazil between 2000 and 2003. The number of tows is presented in the first row followed by the mean catch rate (± SE) and the maximum value in parentheses.

Species	2000	2001	2002	2003	Total
Southeast–South					
Argentine hake	224 20.0 ± 4.2 (497.2)	1,955 183.3 ± 8.3 (6,232.9)	4,044 171.3 ± 7.9 (9,978.0)	2,736 58.0 ± 4.7 (3,601.0)	8,997 135.0 ± 4.3 (9,978.0)
Argentine shortfin squid	224 48.2 ± 14.8 (1,992.9)	1,955 27.3 ± 2.9 (2,473.0)	4,046 199.4 ± 19.1 (48,750.0)	2,736 16.0 ± 1.8 (2,545.9)	8,999 101.6 ± 8.7 (48,750.0)
Silver John dory	224 105.7 ± 18.8 (1,944.9)	1,955 110.2 ± 9.7 (7,634.7)	4,046 340.4 ± 8.9 (10,765.8)	2,736 25.6 ± 4.5 (8,570.0)	8,999 40.7 ± 2.6 (10,765.8)
Monkfish	224 12.5 ± 1.9 (165.9)	1,955 27.7 ± 1.1 (859.3)	4,046 29.3 ± 2.7 (2,914.2)	2,736 11.9 ± 1.0 (336.0)	8,999 23.1 ± 1.2 (2,914.2)
Brazilian codling	224 5.2 ± 2.1 (386.9)	1,955 12.0 ± 0.6 (805.4)	4,046 9.6 ± 0.4 (952.4)	2,736 2.6 ± 0.3 (656.0)	8,999 7.8 ± 0.2 (952.4)
Deep-sea shrimp			4,046 0.9 ± 0.1 (60.0)	2,736 22.6 ± 1.3 (695.2)	8,999 2.0 ± 0.1 (60.0)
Total	224 183.2 ± 25.1 (2,145.0)	1,952 394.5 ± 13.6 (7,736.0)	3,545 489.4 ± 23.6 (48,750.0)	2,134 159.9 ± 8.9 (6,837.0)	7,893 368.9 ± 11.5 (48,750.0)
Northeast–North					
Black grouper			497 74.8 ± 5.9 (1,280.0)	601 102.8 ± 4.9 (695.2)	1,089 90.1 ± 3.8 (1,280.0)
Deep-sea shrimp			497 0.47 ± 0.07 (12.2)	601 0.03 ± 0.02 (5.3)	1,089 0.23 ± 0.03 (12.2)
Total			497 86.4 ± 6.1 (1,280.0)	601 124.4 ± 4.9 (820.0)	1,089 107.2 ± 3.9 (1,280.0)

surpassed, between 2001 and 2003, the total recommended catch (2,215 t) and total biomass decreased nearly 50% from 2003 onwards (Anonymous, 2007). Chartered trawlers contributed to 38.4% (1,018.3 t) and 52.7% (1,952.9 t) of the total landings in 2001 and 2002, respectively. In the following year, total catch was maintained at the 3,000 t level, nearly 90% being produced by national vessel operations. Considering that over 160–170 national trawlers contributed annually to those catches between 2001 and 2003 in contrast to six chartered units, it is evident that the latter represented a major impact on the hake stock, and their coexistence with the national fleet would only have reduced the species abundance to more critical levels (Perez and Pezzuto, 2006; Anonymous, 2007). Similar scenarios could be described for the monkfish and the Brazilian codling, although both species were not major targets of trawlers possibly being avoided by the net arrangement in the former case (Perez et al., 2002a) or by exploiting a geographic area where the latter species is not particularly abundant (Haimovici et al., 2006b). Finally, deep-sea shrimp exploitation by chartered trawlers has been characterized by a concentration of effort on relatively restricted areas of the slope where nearly 80% abundance reductions have been estimated between 2003 and 2004 (Pezzuto et al., 2006b; Anonymous, 2007). Whereas complete assessments are still required, it is evident that such valuable resources will accommodate only a few highly controlled vessels (Anonymous, 2007).

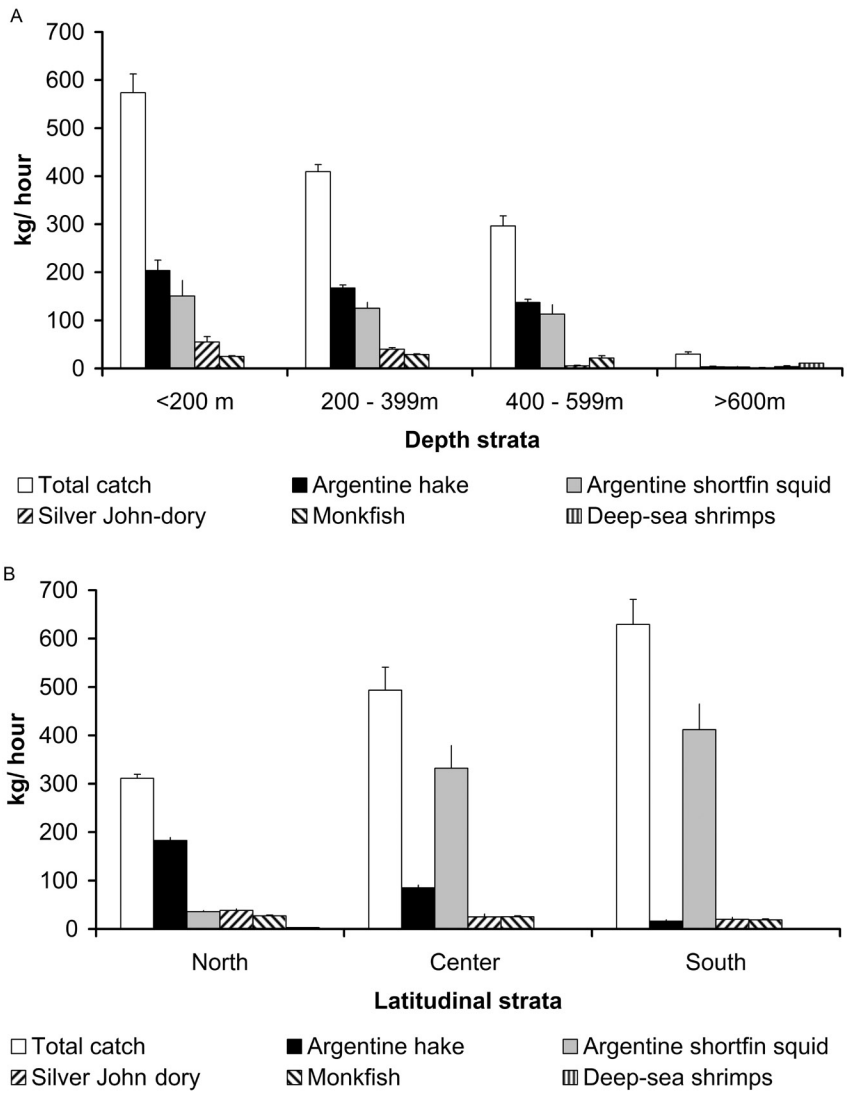

Figure 7.—Catch rate (kg/h) variability of the main components of the catches produced by chartered trawlers off Brazil from 2000 to 2003. A. Depth strata; B. Latitudinal strata (North: north of lat. 25ºS; Center: lat. 25º–lat. 29ºS; South: south of lat. 29ºS). Bars represent mean values. Vertical lines represent one standard error.

In summary, the recent Brazilian chartering program has proven to be an efficient instrument to both explore and exploit deep-sea demersal resources of the country's EEZ. Because of the fragility and generally limited potential yields of these resources (Perez, 2006), however, eventual benefits produced by chartered trawler operations to the national industry can be rapidly cancelled out by important abundance reductions as generated by the intense removals required to match these trawlers' profit demands. Chartering trawlers for deep-water fishing development off Brazil seems no longer viable unless for specific short-term exploratory initiatives in areas deeper than 1,000 m within the country's EEZ or in international waters. Even so this process must be ruled by precaution, intense observation, and control.

Acknowledgments

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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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