Northwest Atlantic Fisheries Organization

Serial No. N4505 **NAFO SCR Doc. 01/117**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2001
(Deep-sea Fisheries Symposium – Oral)

Deep-sea Fishery off Southern Brazil: Recent Trends of the Brazilian Fishing Industry

by

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Abstract

Deep-sea fishing has been considered one important alternative for the required fishing effort reduction on the continental shelf off southern Brazil. In 1998, the Department of Fishery and Aquaculture, Ministry of Agriculture (Brazil), launched a deep-sea fishing program based on the chartering of foreign vessels to national companies, as a measure to stimulate the redirection of fisheries towards unexploited fishing grounds within Brazilian EEZ. As a result deep-sea fishing operations have been recently conducted off southern Brazil by vessels originally from Spain, Korea, Portugal, Japan and the U.K. These operations have been monitored by observers and by satellite Vessel Monitoring Systems, as part of a scientific cooperation program established with the University of "Vale do Itajaí" since October 2000. Catches per trip as large as 262.8, 49.6, 44.5, and 196.2 mt were reported for trawling, longlining, gillnetting and potting operations respectively. Several fishing areas 200 to 866 m deep were identified as productive grounds for valuable resources including the monkfish *Lophius gastrophysus*, the silver john dory *Zenopsis conchifer*, the wreckfish *Polyprion americanus*, the pink cusk-eel *Genypterus brasiliensis*, the red crab *Chaceon* spp., and the short-finned squid *Illex argentinus*. Apart from the wreckfish, which is already fully exploited by the national fleet, sustainable fishing potentials of the other species are currently unknown and urgently required.

Introduction

The demersal fishery in southern Brazil developed during the 1970´s when trawlers started to operate on the continental shelf (shallower than 100 m) aiming principally sciaenid fish and penaeid shrimps (Valentini *et al*., 1991; Haimovici *et al*., 1997). Deep-water fishing initiated in 1973 as a handline fishery for the wreckfish (*Polyprion americanus*) on the upper slope was developed. This fishery was gradually replaced by bottom gillnets and bottom longlines; the former mostly used for shark fishing (Barcellos *et al*., 1991; Haimovici *et al*., 1997; Peres and Haimovici, 1998). In addition, a short-lived deep-water pot fisheries directed to the red crab (*Chaceon* spp.) was attempted during the 1980´s (Lima and Branco, 1991). Because the availability of profitable deep water resources was poorly known and fishing in deep bottoms was risky to the technologically limited and mostly trawling-oriented local fleet, industrial fishery off southern Brazil remained concentrated on the continental shelf until the end of the 1990´s, in spite of serious overfishing trends observed in most traditional targets (Valentini *et al*., 1991; Haimovici, 1998; Castro, 2000).

Expanding the fisheries to unexploited deep grounds has been considered one alternative to the required effort reduction on the continental shelf off southern Brazil. In that sense, a few initiatives of the Brazilian government were conducted in order to map the deep ocean floor and to evaluate potential fishing resources in deep waters, none of them with promissory results (Yesaky *et al*., 1976; Vooren *et al*., 1988; Haimovici and Perez, 1991; Haimovici *et al*., 1994). Aside from the wreckfish and the school shark (*Galeorhinus galeus*), already commercially exploited by the longline and gillnet domestic fleet, the argentine squid (*Illex argentinus*) and the silver john dory (*Zenopsis conchifer*) were considered with some fishing potential although uncertainty remained about favorable

markets and more efficient fishing technologies (Yesaky *et al*., 1976; Vooren *et al*., 1988; Haimovici and Perez, 1991; Haimovici *et al*., 1994).

In 1998, the Ministry of Agriculture (Brazilian Government) launched a deep-water fishing program based on the chartering of foreign vessels by national companies, as an attempt to improve the knowledge on potential resources, to evaluate the profitability of deep-water fishing operations and to absorb adequate technologies for deep-water fishing, handling and processing within Brazilian EEZ. Such program was implemented in southern Brazil in the year 2000 as chartered vessels started to operate in areas 200-900m deep using pots, bottom longlines, bottom gillnets and otter trawls. Monitored by observers and a satellite Vessel Monitoring System (VMS), these operations have provided comprehensive information, which has been essential to produce scientific subsidies for a deep-water fishing policy. The aims of this paper is to describe the fishing trends of the chartered fleet, including the dynamics of fishing operations, main fishing grounds, catch composition and catch rates, as a preliminary analysis of the future development of deep-sea fisheries in southern Brazil.

Material and Methods

The fleet

This study monitored the operations of four types of factory fishing vessels. Spanish longliners were 27 to 40 m long and were powered by 840 to 1,100 HP main engines (Table 1). These vessels operated 6,500 to 13,500 hooks per day, using segmented groundlines. Hooks were baited with squid or sardines. Fishing licenses restricted, since 2001, longline operations to areas deeper than 600 m.

Originally from the UK and Spain, monitored gillnet vessels ranged from 26 to 40 m in length and their main engine ranged from 528 to 1,000 HP (Table 1). The fishing gear consisted of up to four sets of four hundred nets. These nets were 50 m long, 13.5 meshes high and mesh size was 280 mm (stretched mesh). During each haul, these nets were connected in a single set, deployed at night and for nearly four days. Gillnetters were licensed to operate within the 21°S-33°S parallels and beyond the 100 m isobath until the offshore limit of Brazilian EEZ. Vessels entering the fishery in the year 2001 had pre-determined fishing areas (21°S-25°S; 25°S-29°S; 29°S-33°S) within which fishing effort should be shifted every three months of operation.

Stern trawlers, originally from Korea and Portugal, were 52 and 60 m long and powered by 2,200 and 1,700 HP engines respectively (Table 1). These vessels employed otter trawls with headropes ranging from 37 to 80 m and oval 2,500 kg steel doors. When operating on rough bottoms 18 to 24 inches iron bobbins and rubber rollers were rigged to the groundrope. The meshes at the codend measured 60 to 135 mm (stretched mesh). Hauls were nearly four hours long and were conducted at 3.0-3.5 knots. Trawlers were licensed to operate in areas deeper than 200 m within the Brazilian EEZ. In addition bycatch of the wreckfish (*Polyprion americanus*) and the tilefish (*Lopholatillus villari*), considered fully exploited in areas shallower than 600 m, was restricted to 5% of the total catch.

Two very different vessels operated on the crab pot fishery off southern Brazil. One, originally from Japan, was the largest vessel fishing in the region; measuring nearly 63 m long and with a 2,000 HP main engine. A second vessel, originally from the UK, was 35.7 m long and had a 650 HP main engine (Table 1). The Japanese vessel operated four sets of 450 pots made of mesh panels attached to a conical frame and baited with skipjack chunks. The second vessel operated four sets of 200 pyramidal pots made of a steel frame, baited with pieces of horse-eye jack and monkfish. In both vessels, the soaking time ranged from 24 to 36 hours.

Data collection and analysis

All chartered vessels operating off southern Brazil were monitored by VMS (Vessel Monitoring System) and had observers assigned to collect onboard information on fishing technology and operations, fishing areas (positions and depth), catch/bycatch composition and biological samples of selected species. These observers were trained by the Chartered Fleet Observers Program (Ministry of Agriculture and University of "Vale do Itajaí", Brazil) according with the fishing gear employed by the assigned vessel. Identification of species (Tables 2 and 3) and the description of fishing gear and fishing operations were completed in land from collected specimens and photographic/videographic material produced during the trip. Positions of chartered vessels were mapped in real

time by VMS specific softwares and made available by the Chartered Fleet Tracking Program (Ministry of Agriculture and University of "Vale do Itajaí", Brazil) after each trip.

The descriptive analysis of the fishing trips was conducted from the VMS chart of the vessel positions and through the compilation of fishing data (effort, catch, catch rate, catch composition). Fishing data were pooled by month and/or fishing areas according with the number of available trips and the geographic range of operations. Fishing areas were defined by three latitudinal strata: North (21°-25°S), Center (25°-29°S) and South (29°-34°S). Spatial fishing patterns of the different vessels were further assessed through the mapping of effort, catch and catch rate data.

Results

Longline fishery

Three longline vessels operated off southern Brazil (29°-34°S) between March and October 2000 (Table 1). The first monitored vessel conducted three fishing trips and produced nearly 80% of the recorded longline hauls (186 hauls). These trips started in March 2000, off the northern extreme (29°S) and moved progressively southward concentrating around 32°-34°S and 500-600m depths. In August and September other two vessels engaged on a single monitored trip each, operating mostly between 31° and 34°S and 200-300 m deep grounds (Fig. 1 and 2).

All vessels targeted the wreckfish (*P. americanus*), which composed 77.5-93.8% of the total processed catch (Table 4). Other 15 species were retained and processed including, the pink cusk-eel (*Genypterus brasiliensis*, 0.87-8.64%), the school shark (*G. galeus*, 4.7-13.3%) and the tilefish (*L. villarrii* 0.23-4.57%) (Table 4). These species were particularly important in the processed catch composition in August and September when all three vessels were operating simultaneously, two of them in areas shallower than 400 m. Another 11 teleosts, 5 elasmobranchs and one seabird were reported in the bycatch (Tables 2 and 3).

Catch rates of the wreckfish fluctuated around 10.2 kg.100 hooks^{-1} (± 0.6 SEM) reaching up to 75 kg.100 hooks^{-1}. During the first three months, wreckfish catch rates did not surpass 10 kg.100 hooks^{-1}. Between July and September, however, catch rates were at maximum, but decreased sharply towards the end of the period. Interestingly the first vessel to enter the fishery operated during the first three months with nearly twice as many hooks per set as in the last three months (Fig. 2). At least part of the wreckfish catch rate variation seems to have occurred in spite of such change of effort. The largest concentrations of the wreckfish were found at the southernmost extreme of the fished area. Efficient catches of the pink cuskeel and the tilefish were obtained in particular grounds at the center and the northern extreme of the fished area respectively (Fig. 1).

Gillnet fishery

Monitoring of gillnet fishing operations started in January 2001 when only two vessels were at sea concentrating, from January to March, their effort off the coasts of Rio de Janeiro and São Paulo states (23°S-26°S) between 250 to 435 m depths. These vessels were followed in the same period by other two vessels that started exploring southern grounds off Rio Grande do Sul (30°S -31°S) and Santa Catarina (26°S-28°S) states but ended up concentrating in the northern grounds as well. From April to June all vessels but one newcomer vessel moved gradually towards the southern grounds concentrating between 27°S and 32°S (Fig. 3).

The monkfish was the only target of gillnet vessels constituting, in general, more than 90% of processed catch (Table 2 and 5). In addition, a total of 35 bycatch species were also recorded (Table 2 and 3), out of which the red crab, the wreckfish, the tilefish, the Gulf hake, and few elasmobrachs, including the angel shark and rays of the Rajidae family were retained as incidental catch and were also processed in the vessel's factory (Table 5). These elements became progressively important especially by the end of the study period when catches concentrated in the southern areas where the monkfish was less abundant. Three species of seabirds were occasionally reported (Table 3).

The mean catch rate of the monkfish was 1.62 kg.net^{-1} (± 0.06 kg.net^{-1} SEM). They were frequently larger than 3.0 kg.net^{-1} in the northern grounds and tended to decrease sharply from January to March (Fig. 4). This pattern motivated the fleet displacement to the southern grounds from April onwards where catch rates were lower than in

the north. Apparently, operations on this less productive area were accompanied by an increase of individual effort; i.e. the number of nets used per haul (Fig. 4).

Trawl fishery

Two non-overlapping trawling operations were monitored between October 2000 and June 2001 (Table 1). The first trawler operated between 23°40'S and 34°02'S and conducted 302 hauls as deep as 460 m (Table 1, Figure 5). Fishing initiated in October at 26°S and progressed southwards until late November. In this period, fishing effort was concentrated in two areas at 29°S and 31°S (Fig. 6). The trip continued northwards, with exploratory tows, until reaching two important fishing grounds at 26°S and 24°S on which trawling was conducted most days of December and January respectively (Fig. 6). The second vessel operated between 24°48'S and 34°36'S and conducted 256 tows as deep as 352 m (Table 1). Trawling operations initiated in late May and extended through mid June mostly at 28°S. The second half of the trip was conducted at southern grounds between 32°S and 34°S (Figure 6).

Processed catch between October and January, was mostly composed by the silver john dory (32.3- 70.4%). In December and January, the argentine squid (46.3%) and the argentine hake (29.4%) were also major components respectively (Table 6). The monkfish, the Atlantic cutlassfish and skates of the Rajiidae family were the main components of the second vessel processed catch. Interestingly the silver john dory was apparently rejected by this vessel's crew possibly due to unknown market possibilities. A total of 34 teleosts and 3 elasmobranchs were also reported in the bycatch of both monitored trips (Table 2 and 3) including the angel shark, the Gulf hake and other 10 species also processed in the vessel's factory.

The trawler operating from October 2000 to January 2001 obtained highest catch rates in fishing grounds north of 25°S. Most of this catch was sustained by silver john dory and argentine hake aggregations (281.3 $kg.hour^{-1}$ ± 107.4 SEM and 101.7 $kg.hour^{-1}$ ± 24.5 SEM respectively) (Figure 6 and 7). Dense concentrations of the former species were also found at 26°S although the main fished component in this area was the argentine squid (110.0 $kg.hour^{-1}$ ± 30.9 SEM) which sustained maximum catches per tow of 7,440 kg (Figure 6 and 7). In May-June 2001, highest catch rates were obtained in the southern area and were mostly composed by the Atlantic cutlassfish (184.0 $kg.hour^{-1}$ ± 38.0 SEM).

Pot fishery

Monitoring of the Japanese vessel pot fishing operations started in December 2000, and included two complete 60 days fishing trips. Fishing effort during these trips was concentrated on 200-900 m deep muddy bottoms at the southernmost extreme of Brazilian EEZ (Fig. 8). Both the high, and apparently constant, catch rates obtained by this vessel and the increased importance of deep-sea crabs in the monkfish bycatch (Table 5) lead to the entry of a new and much smaller vessel operating with pots off southern Brazil in May 2001 (Table 1).

Most of the catches were obtained in the slope grounds off southern Santa Catarina and Rio Grande do Sul states (Fig. 8), between 326 and 866 m depths, and were composed mostly of the red crabs of the genus *Chaceon* (probably *Chaceon quinquedens* and *C. ramosae*). In addition a few teleosts including the pink cusk-eel and the Gulf hake, as well a spider crab, were also reported as components of the small bycatch (Table 2 and 3)

The vessels differed in both effort (400 to 500 $pots.haul^{-1}$ for the Japanese vessel and from 100 to 300 $pots.haul^{-1}$ for the UK vessel) and catch rates (mean 2.7 ± 0.07 SEM $kg.pot^{-1}$ and 1.8 ± 0.12 SEM $kg.pot^{-1}$, respectively). Such differences coupled with the small overlapping of their respective fishing areas may have accounted for a substantial portion of the observed geographical pattern in the catches. It is suggested, however, that the best catch rates were obtained near the southern limit of the fishing area, and especially in latitudes between 34 and 35°S (Fig. 8). Catch rates were also highly homogeneous throughout the depth strata with larger values being observed between 400 and 800 m (Table 7).

Discussion

The ongoing commercial exploitation of deep grounds off southern Brazil by chartered foreign vessels has been characterized, as compared to the domestic fishing practices, by (a) long term fishing operations, (b) technological adaptability to detect profitable fishing areas and to improve catch efficiency in unexpected and changing conditions, (c) onboard fish handling and processing and (d) the expansion of international market possibilities of previously discarded or poorly known species. After nearly two years a few high-valued deep-water species have been efficiently caught and shown to sustain profitable operations. While such results have been obtained faster than by any previous deep-fishing research program, they have also raised important concerns regarding sustainability of deep-water fishing and the impact on non-target and juvenile organisms as well as on the deep-sea environment as a whole. Intense monitoring of the chartered vessels between March 2000 and June 2001 provided a preliminary assessment of the deep-water fishing trends and scientific subsidies for the sustainable development of such fisheries off southern Brazil.

Fishing operations were concentrated, either as fishing target or incidental catch, on few and mostly high-valued species including the wreckfish, the monkfish, the silver john dory, the argentine hake, the pink cusk-eel, the school shark, the argentine squid and the red crab. All these species have been previously reported by fishing surveys, as occurring on outer shelf and upper slope grounds. Some of them, as the silver john dory, school shark and the argentine squid, have been regarded as with some fishing potential (Yesaki, 1976; Vooren *et al*., 1988; Haimovici and Perez, 1991; Haimovici *et al*., 1994). Other species such as the wreckfish and the red crab have been subject of commercial fisheries, the latter in a similar vessel chartering program (Lima and Branco, 1991; Peres and Haimovici, 1998).

Handline fishing for the wreckfish started in 1973 being gradually replaced by longline operations. Annual catches between 1989 and 1995 ranged between 1,079 and 2,772 t and the fishery was characterized by the depletion and recovery, after several years, of adult fish aggregations on individual fishing grounds (Haimovici *et al*., 1997; Peres and Haimovici, 1998). Elevated catch rates have been normally obtained during winter months as reproductive concentrations become available to the longline fishery. Recently the species has been considered fully exploited by domestic longline fleet off southern Brazil, and highly susceptible to overfishing (Peres and Haimovici, 1998)

During the study period the wreckfish has been caught by all but pot vessels. In particular longliners, mostly targeting this species, exploited traditional fishing grounds and experienced both seasonal and effort-induced catch rate variation. Highly efficient, chartered longliners introduced a substantial addition to the already excessive fishing effort on the wreckfish off southern Brazil (Peres and Haimovici, 1998). This fact motivated a government measure, effective from 2001 onwards, restricting the longline chartered operations to areas beyond 600 m depths where wreckfish stock abundance was unknown. This management measure, which further intended to force the exploration of deeper unexploited grounds, coupled with unprofitable catch rates and market limitations of frozen wreckfish, discouraged longline operations that were greatly reduced in the year 2001.

Commercial concentrations of the monkfish in deep grounds off southern Brazil were not known until the year 2000 when some local trawlers expanded their fishing grounds to the outer shelf and upper slope and the chartered fleet started to operate in this area as well. The species had been caught in grounds as deep as 300 m, by trawl surveys conducted off Rio Grande do Sul state in 1986 and 1987, but no fishing potential had been detected at the time (Haimovici *et al*., 1994). Highly motivated by elevated international prices, the gillnet fishery for monkfish showed that the resource has a continuous distribution along southern Brazil, between the 200 and the 600 m isobaths, with particularly dense concentrations at 24-26°S and 29-31°S latitude strata. Gillnet catch rate trends suggested that these concentrations, however, tend to decrease fast in response to intense effort. In order to maintain profitable catches, vessels were inclined (a) to move to new fishing grounds and (b) to increase the number of nets used in their operations. These patterns, associated with the recent uncontrolled entry of small domestic trawlers aiming mostly the monkfish, indicated that the assessment the monkfish stock is urgently required. While intensive biological sampling has been conducted to that end, a precautionary system of rotation of fishing latitudinal strata has been adopted since mid 2001, as an attempt to spread the effort and avoid sharp abundance declines of particular aggregations. Effort control and biological measures must be considered as soon adequate population data becomes available.

Yesaky *et al*. (1976), from exploratory fishing surveys conducted in the early 1970's, noted a moderate fishing potential of the silver john dory on the slope waters off southern Brazil. This potential was not confirmed by later deep-water trawl surveys although it was argued that the species probably had mixed pelagic-demersal habits becoming only partially vulnerable to the bottom trawl net (Haimovici *et al*., 1994). Trawling operations of chartered vessels revealed that this species was abundant, constituting the main fishing component along the entire fishing area, particularly in the northern grounds (29°S). The species biology off southern Brazil is virtually unknown except that reproductive activity was observed in females as large as 36 cm and during the winter months (Haimovici *et al*., 1994). Since the species is to become one of the main targets of deep-trawling in this area, it is also mandatory that adequate biological data and abundance estimation become available in the near future.

The argentine squid was not considered economically important off southern Brazil until recent deep-water trawling operations of both chartered vessels and domestic trawlers have shown catch rates of 100 kg.hour^{-1} and higher. The species sustains the world's largest cephalopod fisheries off southern Argentina (Haimovici *et al*., 1998), and there has been evidences, from surveys catch rates, tunids stomach contents and paralarval concentration, that this squid is relatively abundant on slope waters off southern Brazil (Haimovici and Perez, 1990; Haimovici and Perez, 1991; Santos, 1992; Haimovici *et al.,* 1995). Large catches obtained in December 2000 at 26°S were mostly composed by fully mature males and females (Perez and Silva unpublished data), probably belonging to a local summer spawning population unit (Haimovici and Perez, 1990). As semelpareous, annual and often migratory, the argentine squid sustains seasonal fisheries which have been managed through abundance estimates before and/or during the fishing season (Haimovici *et al*., 1998; Basson *et al*., 1996). Whereas the argentine squid concentrations off southern Brazil may sustain commercial trawling, the assessment of the annual stock abundance and the distinction of the population structure are basic requirements for this fishery development (see Brunetti *et al*., 1998).

Southern Brazil has been regarded as a nursery ground for a population of the Argentine hake that spawns in winter off the coast of Uruguay (Haimovici *et al*., 1994). These concentrations have sustained occasionally commercial catches during the winter off Rio Grande do Sul (Haimovici *et al*., 1989). Chartered trawlers, on the other hand, obtained important catches during January in the northernmost extreme of the fished area (24°S). Although biological information on caught individuals were not available, it is possible that such concentrations belong to a population unit distinct from the previously detected in southern areas. Because the species is intensely caught of Uruguay and Argentina, exploitation potential off southern Brazil may largely depend on the geographic population structure, which deserve further investigation.

The red crab fishery off southern Brazil was firstly attempted in 1984-1985, through the chartering of two Japanese pot vessels. These operations were concentrated between 34°S and 35°S parallels, precisely the area exploited by the recently chartered pot vessels (Lima and Branco, 1991). Catch rates obtained by this former fishery in the beginning of the operations (December 1984) attained 10.28 kg.pot^{-1}, rapidly declining, seven months later, to 0.75 kg.pot^{-1} when the fishery was abandoned (Lima and Branco, 1991). Matsuura (1995) using catch rate data provided by these vessels estimated, using a Leslie depletion model, an initial biomass of 574 t. Considering the entire fished area, such biomass was transformed into a density of 145 kg.km^{-2}, a value 67% smaller than the one estimated for *C. quinquedens* in the adjacent fishing areas of Uruguay (Defeo *et al*., 1990). According to these authors, highest red crab concentrations were found during the summer in northern Uruguayan coast, adjacent to the Brazilian fishing area. During spring, however, catch rates greatly declined tending to increase towards the south (Niggemeyer *et al*., 1990). Considering the hypothesis that the red crab stock exploited off southern Brazil is at least partly shared with the one off Uruguay, it is possible that the catch rate decline observed off southern Brazil in the 1980´s and the subsequent biomass estimation had been influenced by latitudinal and/or bathymetric migratory patterns still not fully understood in the region. It is noteworthy, on the other hand, that recent pot fishing operations have obtained catch rates relatively stable but substantially lower than the ones observed in the 1980´s. Structural differences of the utilized pots, fishing sets and fishing operations may have influenced in the catch rate variation observed in the different periods off southern Brazil and Uruguayan waters. These are only some of the relevant factors that must be completely investigated in order to properly assess the red crab stock and manage its future explotation.

The definition of fishing targets and the evaluation of the bycatch produced by the chartered fleet has been an important issue for the development of deep-water fisheries off southern Brazil. Despite the existence of defined

target species such as the wreckfish, the monkfish and the red crab, it is important to note that all these species and a few others have been frequently caught and valued by all fishing methods. The monkfish for example is not only targeted by the gillnet fishery but also constitute a substantial proportion of the trawlers catch. Gillnetters have demonstrated their interest in their elevated catches of the red crab, as an alternative for unsatisfactory monkfish catch rates. The pink cusk-eel, the tilefish and several sharks and rays have been retained and processed by gillnetters, longliners and trawlers. This pattern suggests that not only catch and effort of this fisheries may not be reliable but also that deep-water fisheries off southern Brazil, as observed in other oceans (Gordon, 2001), may become spasmodic, with versatile vessels easily shifting from one target to another as catch rates oscillate. An even worse scenario is expected as domestic fast-learning trawlers become attracted to the favorable profits and expand their operations to deep grounds. Unless these interactions be taken into account in future deep-water fishing policies, chaotic patterns of exploitation of poorly known species may rapidly lead to the fishery collapse, a situation already established on the continental shelf off southern Brazil (Haimovici, 1998). In that sense bycatch restrictions have already been imposed to the trawlers, but further measures should be considered specially in the southernmost areas where particularly fragile organisms have become increasingly vulnerable such as several low-fecundity sharks (Haimovici *et al*. 1997).

The development of industrial fishing through the chartering of foreign vessels has been a common practice off southern Brazil. In the 1960's double rig trawlers were chartered from the Gulf of Mexico for the development of pink-shrimp (*Farfantepenaeus* spp.) fishery (Valentini *et al*., 1991). In the 1980's chartered Japanese live bait vessels initiated the skipjack tuna (*Katsuwonus pelamis*) pole-and-line fishery, at present one of the most important pelagic fishery off southern Brazil (Andrade, 1998). In both cases foreign vessels were either nationalized or their technology adapted to the local fleet. The recent attempt to develop deep-water fisheries has rapidly identified a few new alternatives for Brazilian offshore fisheries. On the other hand the relatively high fishing power of the chartered fleet has also shown that some of the stocks may not sustain intense deep-water fishing. The nationalization of such large vessels or the expansion of the chartering program, with the entry of new vessels, at the moment, is not recommended and should only be considered as biological patterns of the stocks become better known and as defined scientifically-based policies are implemented.

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 (Brazilian Government) provided funds for this study through a scientific cooperation program with "Universidade do Vale do Itajaí" (MA/SARC 03/2000).

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TABLE 1. Summary of the chartered vessels commercial trips off southern Brazil, monitored by observers between March 2000 and July 2001. LL, long-line; GL, gill-net; T, trawl; P, pot; SEM, standard error. GRT, Gross tonnage; All latitudes and longitudes refer to southern and western hemispheres respectively.

Vessel	Origin	Length (m) GRT Power (HP)	Number of trips	Initial date	Final date	Depth (m) mean±SEM (Min-Max)	Latitude range	Longitude range	Number of hauls	Processed catch (t)
Nêutron (LL)	Spain	39.6 388 840	3	12/03/2000	01/10/2000	516.2 ± 7.5 (270-800)	29°37'-34°25'	47°53'-51°47'	186	140.8
Mar Salada (LL)	Spain	27.3 99 840	1	24/08/2000	04/10/2000	272.2 ± 13.8 (192-421)	31°02'-33°30'	49°22'-50°42'	28	21.1
Nuevo Mar (LL)	Spain	27.0 99 1,100	1	24/08/2000	04/10/2000	215.4 ± 8.7 (159-296)	33°35'-34°03'	50°27'-51°33'	24	19.8
Juno (GN)	UK	37.1 235 1,000	2	13/01/2001	06/05/2001	354.2 ± 3.7 (250-495)	23°40'-30°54'	41°45'-49°12'	93	77.0
Titan (GN)	UK	39.6 319 700	2	03/02/2001	13/05/2001	352.9 ± 6.8 (263-711)	23°40'-30°42'	41°47'-48°50'	90	78.5
Suffolk Chieftain (GN)	UK	38.3 362 960	2	08/02/2001	22/06/2001	353.0 ± 4.4 (223-543)	27°00'-29°23'	43°50'-48°58'	109	54.9
South Coast (GN)	UK	38.3 362 960	1	28/02/2001	28/04/2001	427.1 ± 7.4 (252-565)	23°42'-28°06'	41°25'-44°28'	62	15.6
Antoxo (GN)	Spain	26.7 72 528	3	06/03/2001	27/06/2001	347.4 ± 5.9 (240-490)	25°04'-30°43'	44°46'-48°53'	79	74.1
Joana (T)	Portugal	60 890 1,700	1	26/10/2000	22/01/2001	296.7 ± 3.2 (131-460)	23°40'-34°02'	41°53'-51°35'	302	262,8
Insung 207 (T)	Korea	52 925 2,200	1	23/05/2001	01/07/2001	178.8 ± 3.2 (84-352)	24°48'-34°36'	44°41'-54°29'	256	169,8
Kinpoh Maru 58 (P)	Japan	62.7 349 2,000	2	30/12/2000	20/04/2001	595.9 ± 8.2 (326-866)	33°16'-34°39'	50°27'-52°35'	250	298.6
Royalist (P)	UK	35.7 - 650	1	31/05/2001	06/07/2001	577.6 ± 14.0 (415-805)	28°43'-33°15'	47°23'-51°23'	53	28.8

TABLE 2. Teleosts identified in the catches of the chartered fishing vessels off southern Brazil (23°S - 34°S) between March 2000 and July 2001. ** discarded; ***retained bycatch; **** target species.

Scientific name	Common name	Long-line	Gill-net	Trawler	Pot
Antigonia capros	Deepbody boarfish			**	
Ariomma bondi	Silver-rag driftfish			**	
Bellator brachychir	Shortfin searobin			**	
Bembrops heterurus	Squaretail duckbill			**	
Coelorhynchus coelorhynchus	Granadier		**	**	
Cookeoulus boops	Longfinned bullseye			**	
Conger orbignyanus	Argentine conger	**			
Cynoscion guatucupa	Stripped weakfish			**	
Decodon puellaris				**	
Evoxymetopon taeniatus	Channel scabbardfish		**	**	
Genypterus brasiliesis	Pink cusk-eel	****		**	**
Gymnothorax ocellatus	Caribbean ocellated moray	**			
Hoplunnis tenuis	Freckled pike-conger			**	
Helicolenus dactylopterus	Blackbelly rosefish	***	**		**
Hoplostethus occidentalis	Slimehead	***	**		
Lopholatylus vilarii	Tilefish	****	***		
Lophius gastrophysus	Monkfish		****	****	
Macrorhamphosus scolopax	Slender spinefish			**	
Merluccius hubbsi	Argentine hake	***	**	****	
Micropogonias furnieri	Whitemouth croaker			***	
Mullus argentinus	Red mullet			***	
Notopogon fernandezianus	Orange bellowfish		**	**	
Pagrus pagrus	Red porky	***		***	
Paralichthys spp.	Flounder			***	
Percophis brasiliensis	Brazilian flathead			**	
Peristedion altipinne	Armoured searobin		**	**	
Pinguipes brasilianus	Brazilian sandperch	***			
Polimixia lowei	Beardfish		**	**	
Polyprion americanus	Wreckfish	****	***	***	
Pontinus sp.	Scorpionfish			**	
Porichtys prosissimus	Atlantic midshipman			**	
Priacanthus arenatus	Atlantic bigeye	***	**	**	
Pseudopercis semifasciata	Brazilian sandperch	***	**		
Saurida sp.	Largescale lizardfish			**	
Sciaenoides bergi	Hawkfish		**	**	
Seriola lalandei	Yellowtail amberjack	***	**		
Synagrops bella				**	
Synchiropus agassizii	Spotfin dragonet			**	
Thyrsitops lepidopoides	White snake mackerel			**	
Trachurus lathami	Rough scad			**	
Trichiurus lepturus	Atlantic cutlassfish	**		****	
Umbrina canosai	Argentine croaker			***	
Urophycis brasiliensis	Brazilian codling			***	
Urophycis cirrata	Gulf hake	***	***	***	**
Ventrifossa occidentalis				**	
Zenopsis conchifer	Silver john dory		**	****	

TABLE 3. Elasmobranchs, crustaceans, molluscs and birds identified in the catches of the chartered fishing vessels off southern Brazil (23°S - 34°S) between March 2000 and July 2001. ** discarded; ***retained by-catch; **** target species

		Long-line	Gill-net	Trawler	Pot
Elasmobranchs					
Torpedo puelcha	Atlantic torpedo		**		
Rajiidae	Skate	**	**	***	
Squatina spp.	Angel shark		***	***	
Prionoce glauca	Blue shark		**		
Scyliorhinus retifer	Freckled catshark	**	**	**	
Carcharhinus signatus	Night shark	***	**		
Sphyrna sp.	Hammerhead shark		**		
Squalus sp.	Spiny dogfish	***	**		
Heptranchias perlo	Sharpnose shark		**		
Galeorhinus galeus	School shark	***			
Alopias sp.	Thresher shark	**			
Crustaceans					
Chaceon ramosae/ C.quinquedens	Red crab		***		****
Rochinia crassa	Spider crab		**		**
Hepatus pudibundus			**		
Acanthocarpus alexandri			**		
Calappa augusta			**		
Bathynomus spp.			**		
Molluscs					
Illex argentinus	Argentine squid		**	****	
Birds					
Daption capensis			**		
Puffinus gravis			**		
Procelaria aecnoctialis		**	**		

TABLE 4. Processed catch composition of chartered longline vessels off southern Brazil (23°S - 34°S) between March 2000 and July 2001. Numbers between brackets are column percentages.

	Month							
	March	April	May	July	August	September	October	TOTAL
Number of hauls	14	31	15	7	68	101	2	238
Species								
Polyprion americanus	8,237	27,222	8,133	4,320	44,978	58,614	679	152,076
	(83.28)	(90.56)	(83.78)	(93.81)	(82.39)	(77.51)	(84.24)	(82.13)
Genypterus brasiliensis	352	1,352	839	40	2,721	3,757	0	9,061
	(3.56)	(4.50)	(8.64)	(0.87)	(4.98)	(4.97)	(0.00)	(4.89)
Galeorhinus galeus	0	0	0	0	2,585	4,651	90	7,326
	(0.00)	(0.00)	(0.00)	(0.00)	(4.74)	(6.15)	(13.25)	(3.96)
Lopholatilus villarii	449	170	22	45	639	1,862	3	3,190
	(4.57)	(0.57)	(0.23)	(0.98)	(1.17)	(2.46)	(0.44)	(1.72)
Other elasmobrachs	0	0	0	0	1,982	556	0	2,583
	(0.0)	(0.00)	(0.00)	(0.00)	(3.63)	(0.74)	(0.00)	(1.37)
Other species	853	1,314	713	200	1,688	6,181	14	10,963
	(8.62)	(4.37)	(7.35)	(4.34)	(3.09)	(8.17)	(2.06)	(5.92)
TOTAL	9,981	30,058	9,707	4,605	54,593	75,621	679	185,154

TABLE 5. Temporal and spatial composition of processed catch of chartered gillnet vessels off southern Brazil (23°S - 34°S) between January and June 2001. Numbers between brackets are column percentages.

	Month						Area			
	January	February	March	April	May	June	North	Center	South	TOTAL
Number of hauls	18	81	113	120	54	47	201	96	136	433
Species										
Lophius gastrophysus	21,460	66,194	43,570	60,760	35,980	23,440	120,400	44,290	85,120	249,810
	(99.92)	(98.25)	(90.01)	(91.39)	(90.76)	(81.21)	(94.52)	(86.64)	(89.75)	(92.31)
Chaceon sp.	0	18	2,439	3,267	1,803	1,761	2,693	4,234	2,360	9,288
	(0.00)	(0.03)	(5.04)	(4.91)	(4.55)	(6.10)	(2.11)	(8.28)	(2.49)	(3.43)
Rajidae	0	60	800	340	680	1880	780	1,180	1,800	3,760
	(0.00)	(0.09)	(1.65)	(0.51)	(1.72)	(6.51)	(0.61)	(2.31)	(1.90)	(1.39)
Polyprion americanus	0	0	0	940	820	885	0	40	2,605	2,645
	(0.00)	(0.00)	(0.00)	(1.41)	(2.07)	(3.07)	0.00	(0.08)	(2.75)	(0.98)
Lopholatilus villarii	0	746	978	280	220	120	1810	534	0	2,344
	(0.00)	(1.13)	(2.02)	(0.42)	(0.55)	(0.42)	(1.42)	(1.04)	(0.00)	(0.87)
Squatina sp.	0	144	440	260	0	200	566	218	230	1,044
	(0.00)	(0.22)	(0.91)	(0.39)	(0.00)	(0.69)	(0.44)	(0.43)	(0.24)	(0.39)
Urophycis cirrata	18	0	158	620	20	0	36	120	660	816
	(0.08)	(0.00)	(0.33)	(0.93)	(0.05)	(0.00)	(0.03)	(0.23)	(0.70)	(0.30)
Other elasmobrachs	0	0	0	0	120	576	0	0	696	696
	(0.00)	(0.00)	(0.00)	(0.00)	(0.30)	(2.00)	(0.00)	(0.00)	(0.00)	(0.26)
Other species	0	180	20	20	0	0	180	20	20	220
	(0.00)	(0.27)	(0.04)	(0.03)	(0.00)	(0.00)	(0.14)	(0.04)	(0.02)	(0.08)
TOTAL	21,478	65,748	48,405	66,487	39,634	28,862	126,466	50,639	93,491	270,623

TABLE 6. Temporal and spatial processed catch composition of chartered trawlers off southern Brazil (23° S - 34° S) between October 2000 and June 2001. Numbers between brackets are column percentages.

	Month/ Year						Area		
	October 2000	November 2000	December 2000	January 2001	May 2001	June 2001	North	Center	South
Number of hauls	20	97	109	76	43	152	111	223	224
Species									
Zenopsis conchifer	7,416	45,700	29,800	41,952	0	1,768	41,844	51,065	33,727
	(70.38)	(58.05)	(32.32)	(51.57)	(0.00)	(2.21)	(57.98)	(27.76)	(33.15)
Illex argentinus	320	5,381	42,700	7,620	13	273	420	55,161	726
	(3.04)	(6.84)	(46.31)	(9.37)	(0.09)	(0.34)	(0.58)	(29.99)	(0.71)
Merluccius hubbsi	880	7,140	7,320	23,880	13	2,678	23,160	12,833	5,918
	(8.35)	(9.07)	(7.94)	(29.36)	(0.09)	(3.35)	(32.09)	(6.98)	(5.82)
Lophius gastrophysus	928	4,576	6,912	6,720	4,789	17,628	6,267	29,188	6,098
	(8.81)	(5.81)	(7.50)	(8.26)	(31.91)	(22.03)	(8.68)	(15.87)	(5.99)
Trichiurus lepturus	200	920	2,040	920	4,978	18,844	240	14,096	13,566
	(1.90)	(1.17)	(2.21)	(1.13)	(33.17)	(23.55)	(0.33)	(7.66)	(13.33)
Rajiidae	0	0	0	0	2,909	15,720	65	7,930	10,634
	(0.00)	(0.00)	(0.00)	(0.00)	(19.39)	(19.65)	(0.09)	(4.31)	(10.45)
Other elasmobrachs	53	4,370	1,320	0	0	321	0	1,453	7,497
	(0.50)	(5.55)	(1.43)	(0.00)	(0.00)	(4.01)	(0.00)	(0.79)	(7.37)
Squatina spp.	80	2,072	805	20	1,642	408	20	5,694	2,980
	(0.76)	(2.63)	(0.87)	(0.02)	(10.94)	(5.09)	(0.03)	(3.10)	(2.93)
Urophycis cirrata	160	2,640	780	120	573	3,35	40	3,102	4,485
	(1.52)	(3.35)	(0.85)	(0.15)	(3.82)	(4.19)	(0.06)	(1.69)	(4.41)
Other species	500	5,926	530	112	90	12,473	112	3,404	16,115
	(4.75)	(7.53)	(0.57)	(0.14)	(0.60)	(15.59)	(0.16)	(1.85)	(15.84)
TOTAL	10,537	78,725	92,207	81,344	15,006	80,018	72,168	183,926	101,744

TABLE 7. Bathymetric distribution of effort and catch rates of red crabs (*Chaceon ramosae* and *C. quinquedens*) of two chartered pot vessels off southern Brazil (23°S - 34°S) between December 2000 and July 2001. (Mean ± Standard Error of Mean).

	Vessel I				Vessel II			
Depth	N	Pots. haul^{-1}	Kg.haul^{-1}	Kg.pot^{-1}	N	Pots. haul^{-1}	Kg.haul^{-1}	Kg.pot^{-1}
300-400	13	450 ± 0	1183 ± 131	2.6 ± 0.3	-	-	-	-
400-500	48	445 ± 2	1272 ± 78	2.9 ± 0.2	7	307 ± 35	370 ± 60	1.3 ± 0.3
500-600	68	449 ± 5	1242 ± 44	2.8 ± 0.1	29	248 ± 10	490 ± 53	1.9 ± 0.2
600-700	55	450 ± 0	1244 ± 58	2.8 ± 0.1	14	253 ± 13	483 ± 48	1.9 ± 0.2
700-800	43	446 ± 3	1202 ± 72	2.7 ± 0.2	1	200	95	0.5
800-900	17	450 ± 0	1035 ± 141	2.3 ± 0.3	1	200	63	0.3

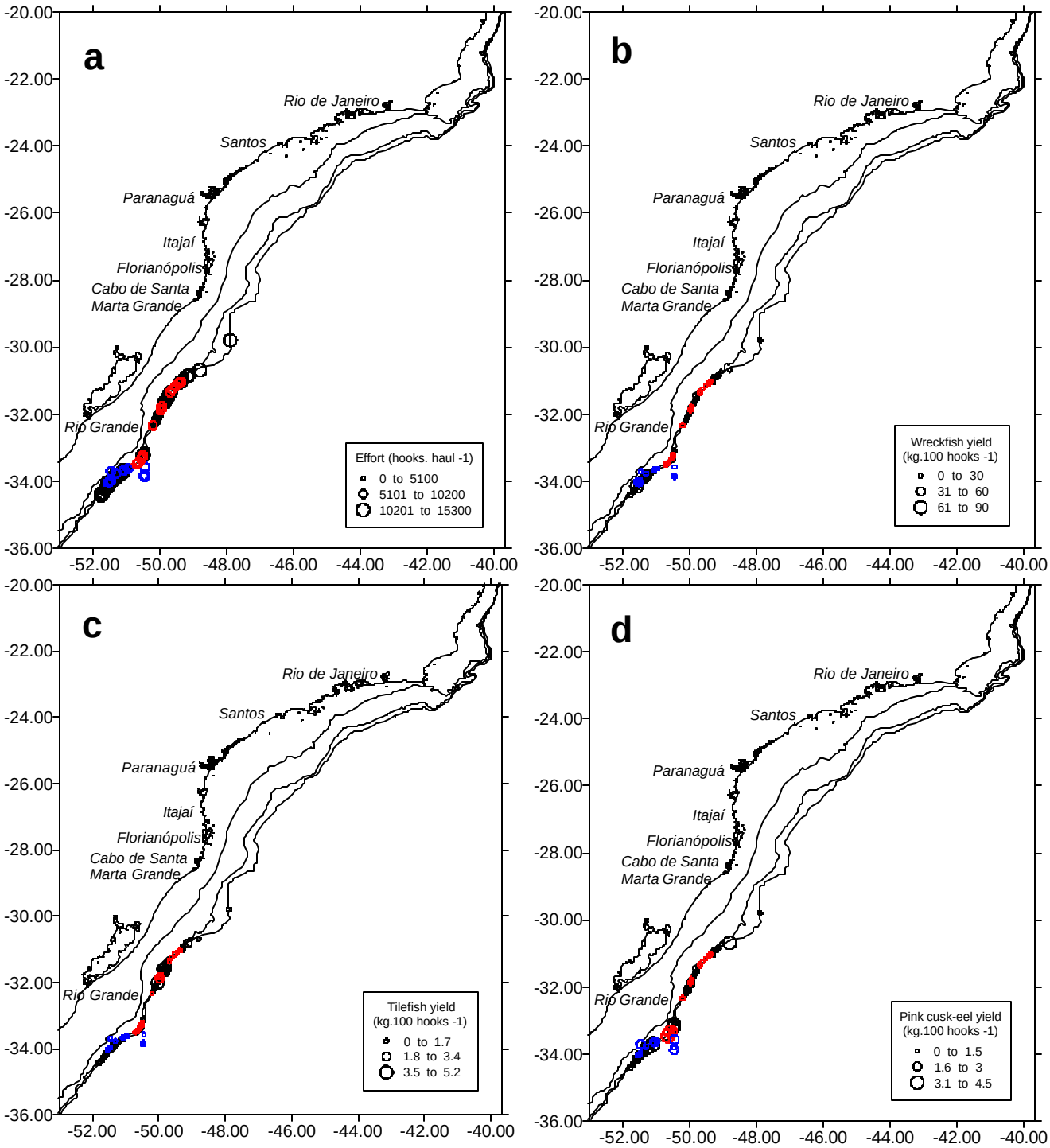

FIGURE 1. Spatial patterns of the chartered longline fishing operations off southern Brazil between March and October 2000. Maps represent distribution of effort (a) and catch rates of the wreckfish (*Polyprion americanus*) (b), tilefish (*Lopholatilus villarii*) (c) and pink cusk-eel (*Genypterus brasiliensis*) (d). Latitudes and longitudes are decimal transformed.

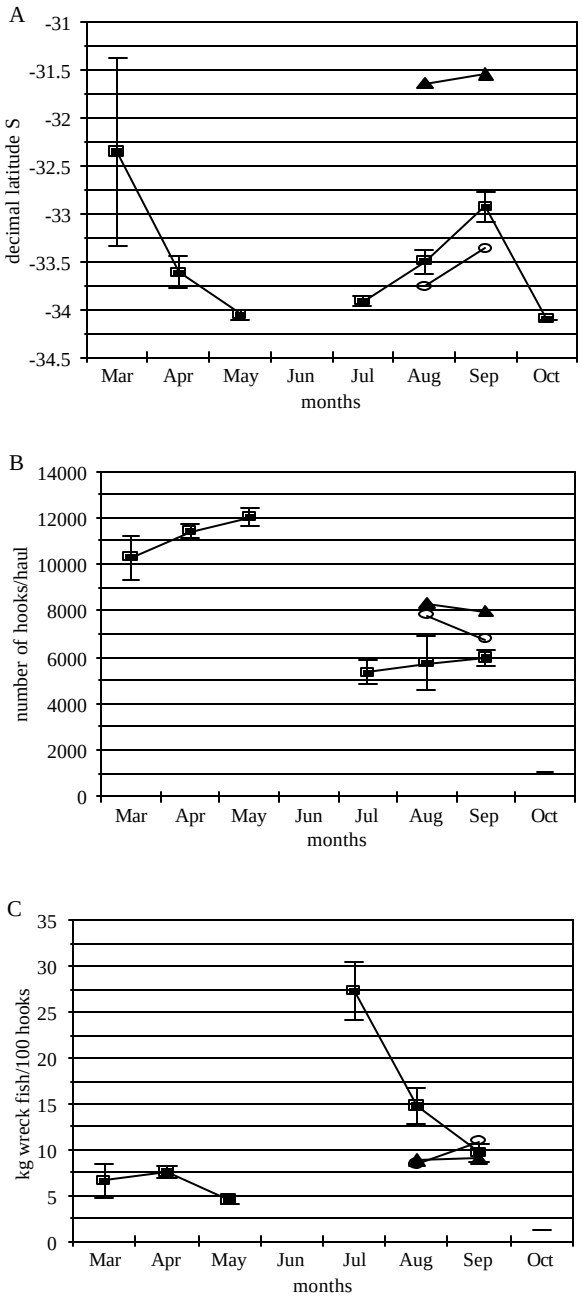

FIGURE 2. Mean spatial and temporal catch patterns of longline chartered vessels off southern Brazil between March and October 2000. A, latitudinal variation of hauls; B, number of hooks per set; C, wreckfish catch rate (kg.100 hooks^{-1}). Vertical bars represent one standard error of the mean. Different symbols depict different vessels.

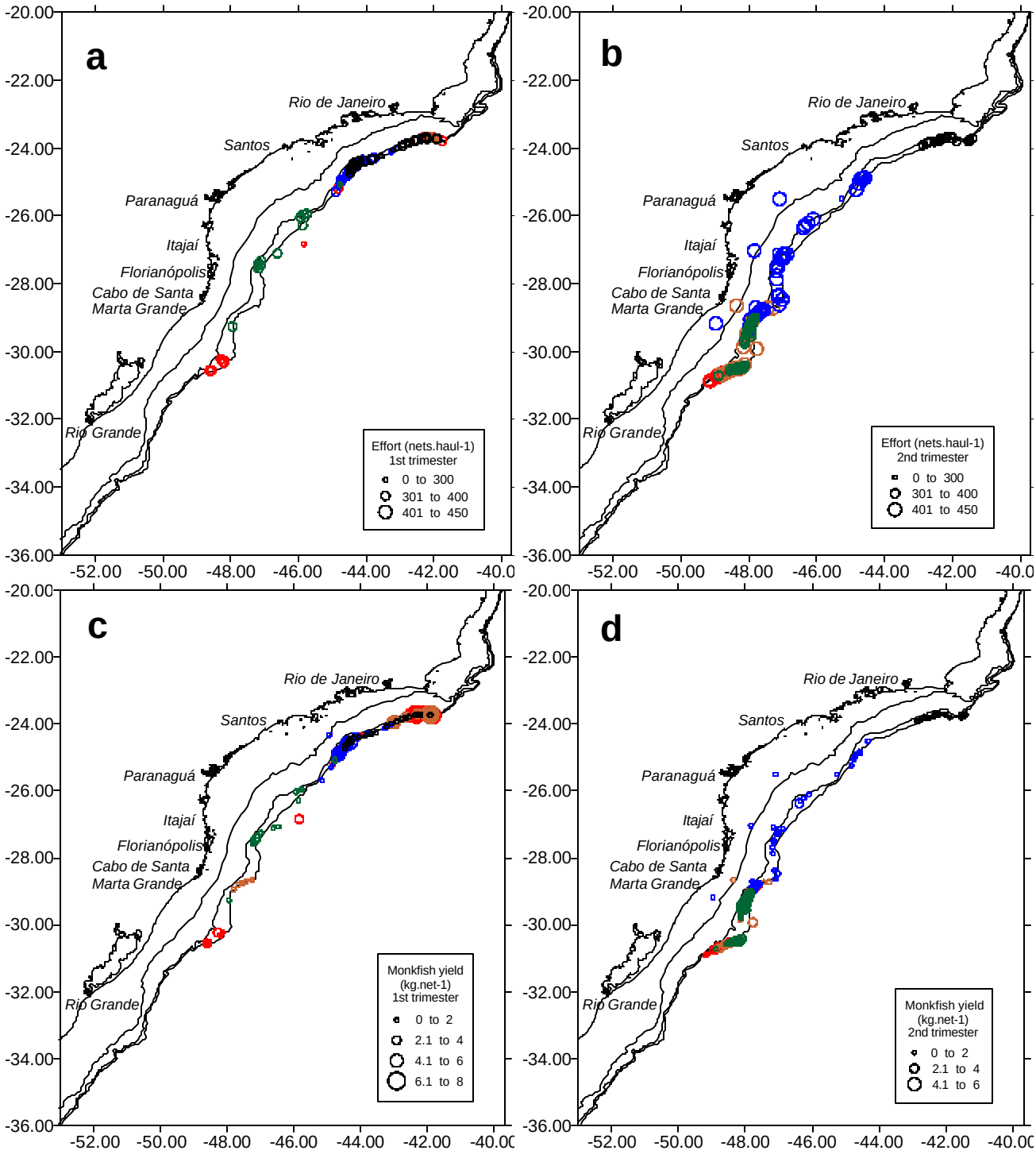

FIGURE 3. Spatial and temporal patterns of the chartered gillnet fishing operations off southern Brazil between January and June 2001. Maps represent effort and monkfish catch rate in the first (a,c) and second (b,d) trimesters of 2001. Latitudes and longitudes are decimal transformed.

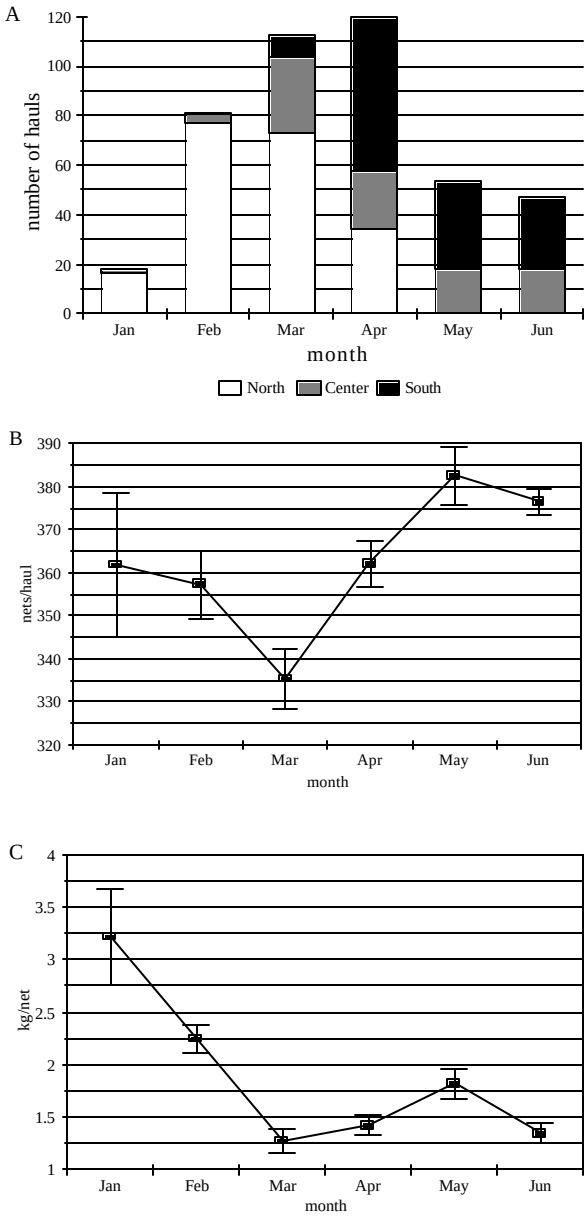

FIGURE 4. Mean spatial and temporal catch patterns of gillnet chartered vessels off southern Brazil between January and June 2001. A, distribution of hauls per fishing areas; B, number of nets per haul; C, monkfish catch rates ($kg.net^{-1}$). Vertical bars represent one standard error of the mean.

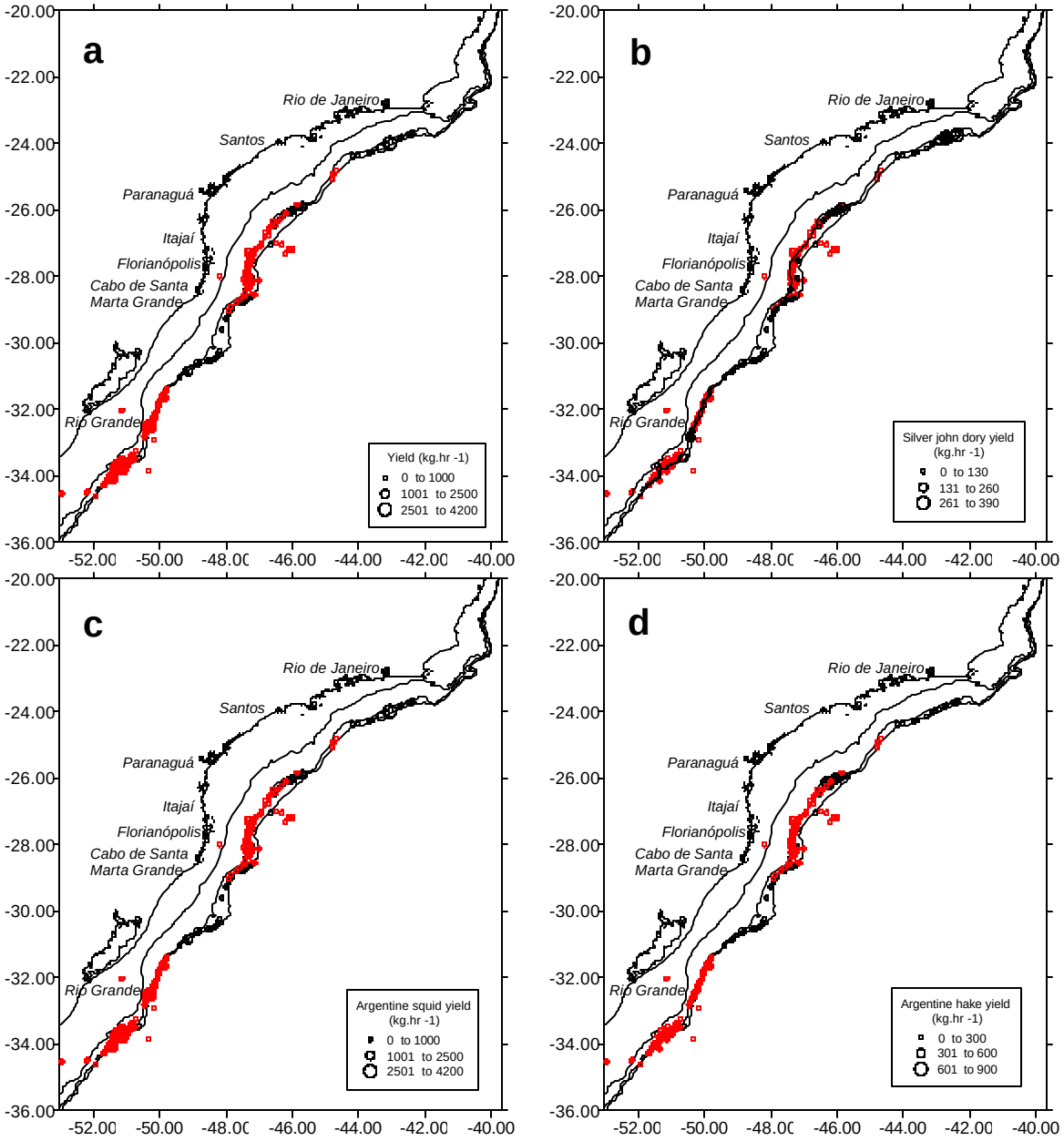

FIGURE 5. Spatial and temporal patterns of the chartered trawling fishing operations off southern Brazil between October 2000 and July 2001. Maps represent spatial distribution of catch rates: a, total; b, silver john dory; c, Argentine squid; d, Argentine hake. Latitudes and longitudes are decimal transformed.

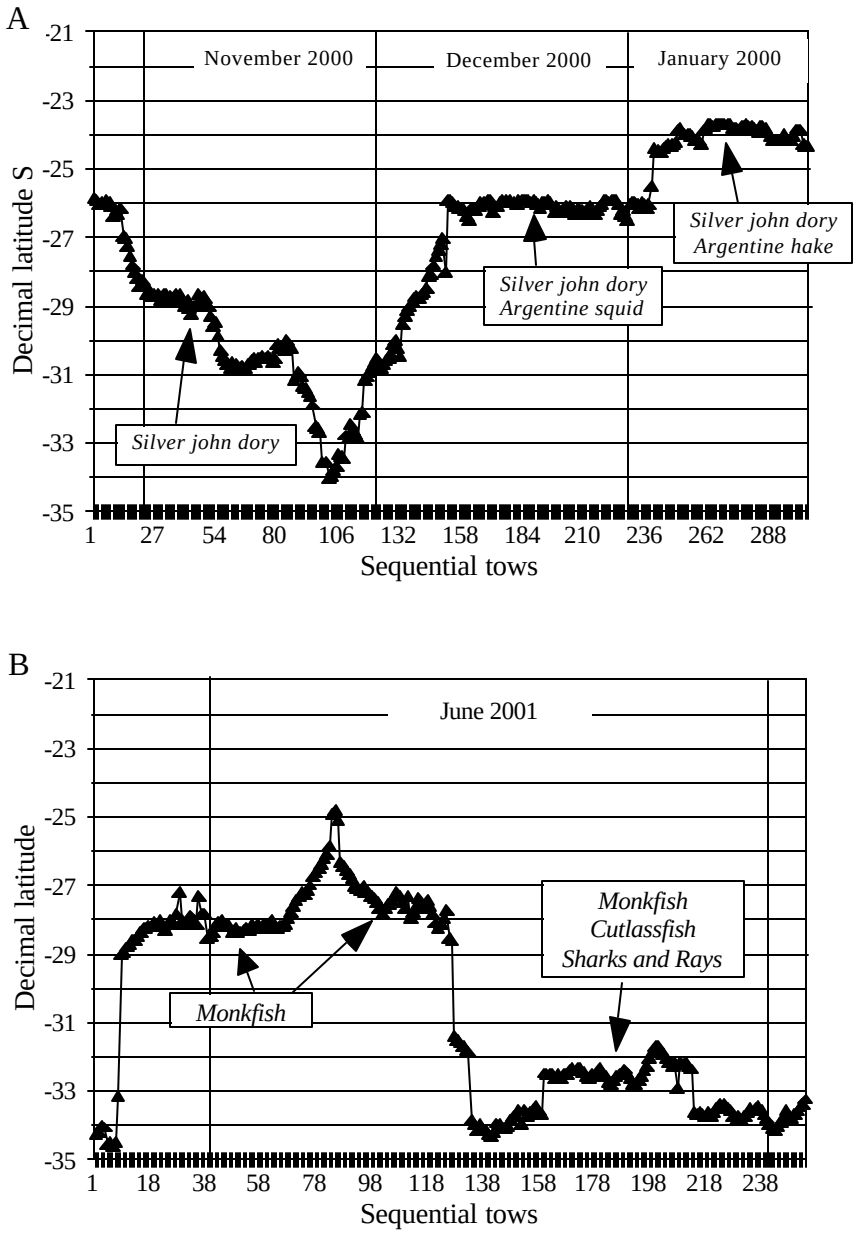

FIGURE 6. Latitudinal distribution of tows conducted by chartered trawlers of southern Brazil from October 2000-January 2001 (A) and May-June 2001 (B). Areas where trawling was concentrated during the fishing trips are indicated along with the main fishing targets.

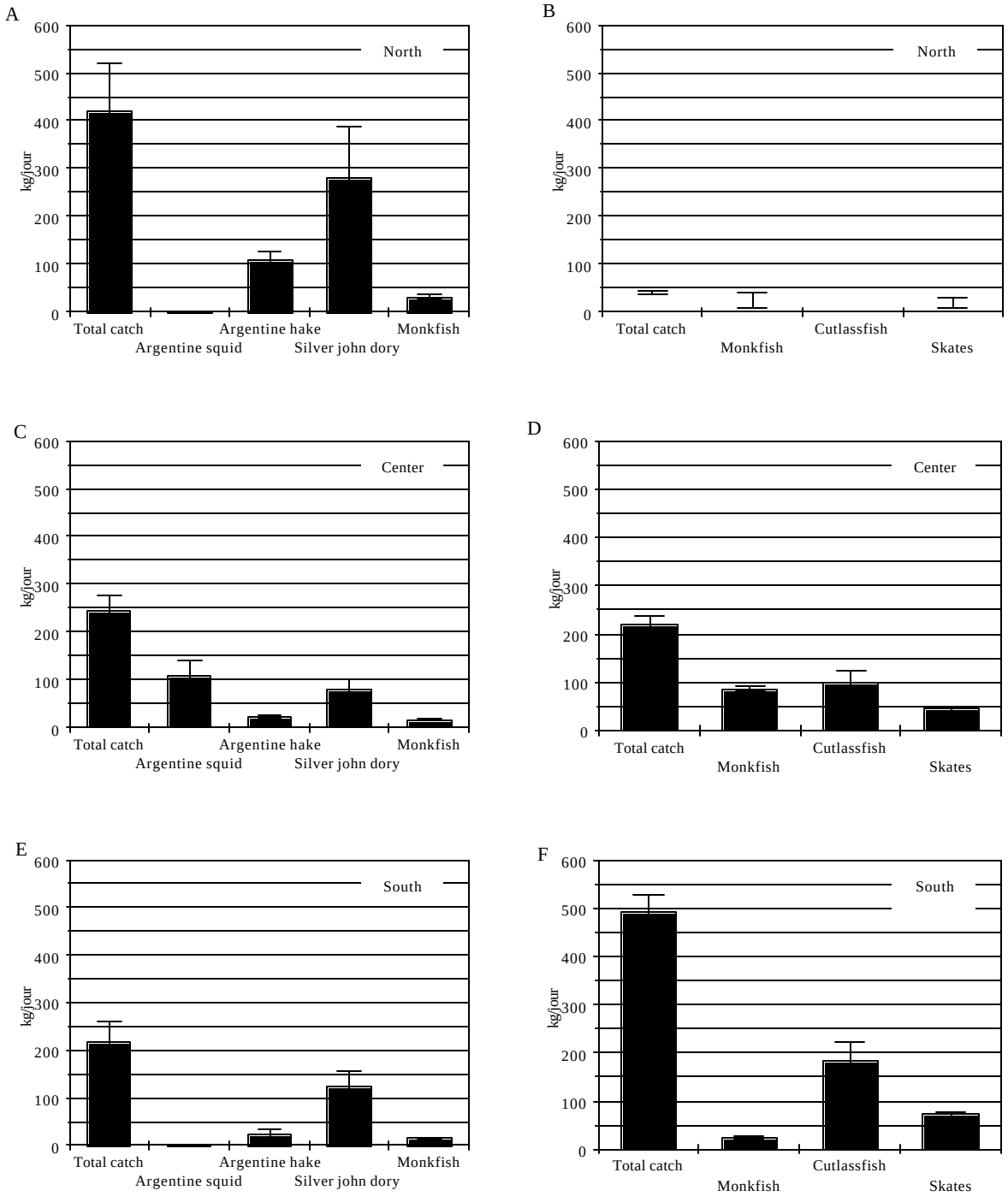

FIGURE 07. Mean catch rates obtained by chartered trawlers between October 2000 – January 2001 (A, C, E) and May-June 2001 (B, D,F) in three latitudinal strata off southern Brazil: North (21°-25°S); Center (25°-29°); South (29°-34°). Vertical bars represent one Standard Error of the Mean.

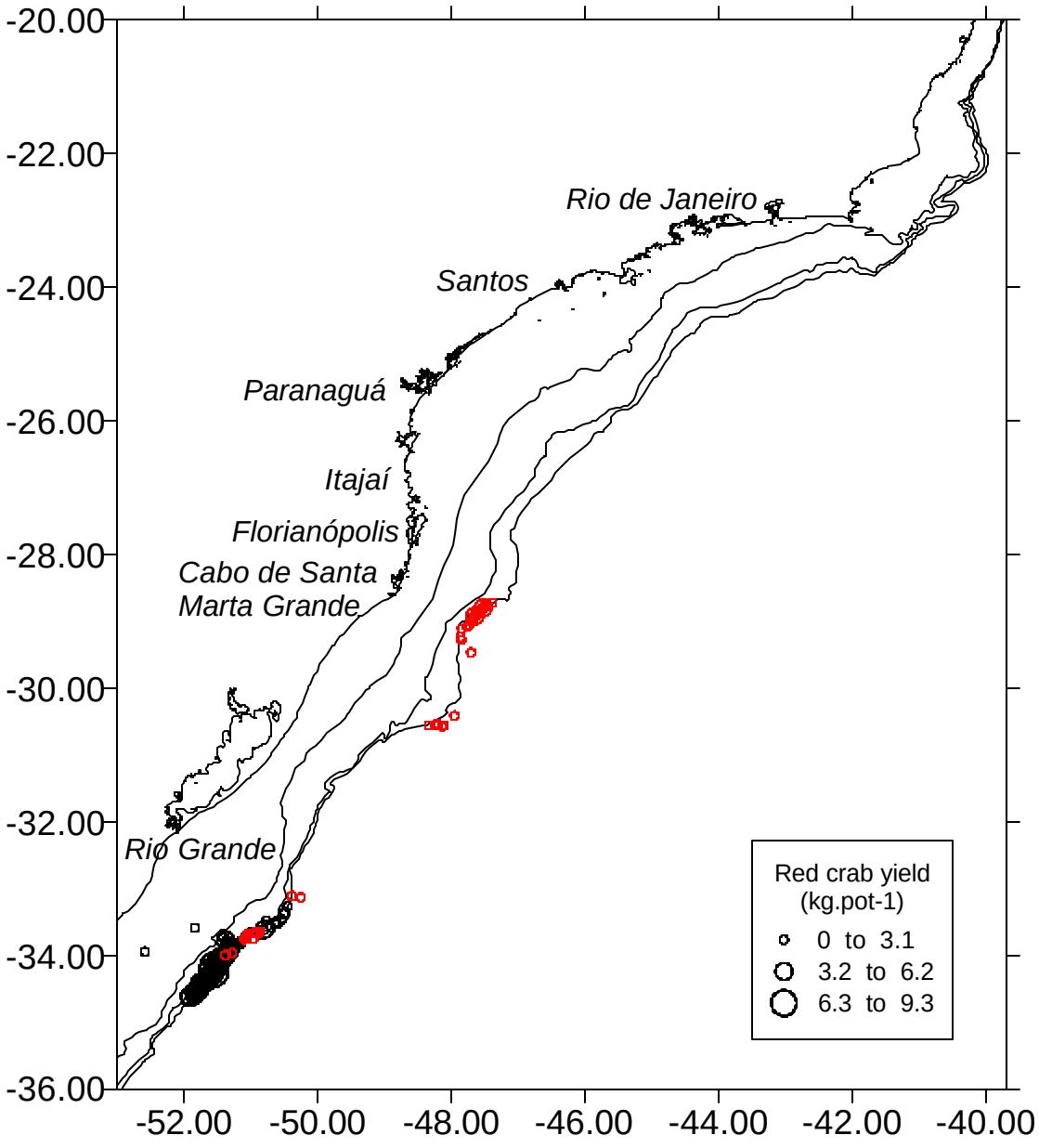

FIGURE 8. Spatial patterns of the chartered pot fishing operations off southern Brazil. Map represents the red crab (*Chaceon* quinquedens and *C.* ramosae) catch rate distribution between December 2000 and July 2001. Latitudes and longitudes are decimal transformed.