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Research Article

Challenges in licensing the industrial double-rig trawl fisheries in Brazil

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ABSTRACT. Bottom trawling is important in Brazilian fisheries and is currently highly multi-specific due to the overexploitation of the original targets; unselective fishing method; very large permitted fishing area and the country's high marine biodiversity. Fishing licensing in Brazil was modified in 2012 and is now based in five criteria: target species; "expected by-catch"; "incidental catches"; fishing method and area of operation. Licenses of trawling fleets exhibit, therefore, dozens of species catchable under the first three criteria. In this paper, we analyze industrial double-rig trawling fleets targeting shrimps and demersal fishes, in order to verify in what extent the new system adhere to the current fishing reality, giving new information to improve the current management regime. A total of 4,194 trips from 191 vessels were studied between 2008 and 2010 in southern Brazil. In spite of depending economically on their targets, the fleets are formally authorized to catch a high percentage of species in common (41 to 71%), and the actual landings revealed an even greater overlapping among them (71 to 82%). Vessels licensed to catch demersal fishes obtained nearly 50% of their revenue from items not included in their licenses. It was concluded that the current system encourages excessive effort concentrations over fishing resources, as they can be legally caught by most vessels irrespective of their licenses. It is suggested that licensing should move from a species-based to a spatial-based approach, by defining smaller management areas according to the respective species assemblages. Landing composition would be, therefore, mostly a biological and technological consequence, making management more reasonable and workable under a multi-specific and mega-diverse scenario.

Keywords: management, fishing licensing, demersal fisheries, fishing dynamics, Brazil.

Desafíos en el licenciamiento de la pesca de arrastre industrial tangonera en Brasil

RESUMEN. La pesca de arrastre es importante en las pesquerías brasileñas y actualmente es altamente multi-específica debido a la sobre-explotación de las especies objetivo originales, al método de pesca no selectivo, las grandes áreas de pesca permitidas y a la alta biodiversidad marina del país. En Brasil, la concesión de licencias de pesca fue modificada recientemente. Se definieron licencias bajo cinco criterios: especies objetivo, fauna acompañante esperable, capturas incidentales, método de pesca y área de operación. Según los tres primeros nuevos criterios, las licencias de las flotas arrastreras exhiben decenas de especies capturables. En este trabajo, se analizaron las flotas tangoneras industriales que capturan camarones y peces demersales, en orden a verificar en qué medida el nuevo sistema se adecúa a la realidad pesquera actual y mejora la gestión. Se estudiaron 4.194 viajes realizados por 191 embarcaciones entre 2008 y 2010 en el sur de Brasil. A pesar de depender económicamente de las especies objetivo, las flotas están autorizadas oficialmente a capturar un alto porcentaje de especies coincidentes (41 a 71%), sin embargo los desembarques actuales muestran incluso una superposición mayor (71 a 82%). Las embarcaciones con licencia para peces demersales obtuvieron cerca del 50% de sus ingresos a partir de especies no incluidas en sus licencias. El sistema actual favorece excesivas concentraciones de esfuerzo sobre los recursos pesqueros dado que éstos pueden ser legalmente capturados por la mayoría de las embarcaciones, independientemente de las licencias que poseen. La concesión de licencias debería pasar de un enfoque basado en especies a uno basado en áreas de manejo definidas de acuerdo a los respectivos ensambles de especies. De este modo, la composición de los desembarques sería principalmente una consecuencia biológica y tecnológica, haciendo que la gestión sea más razonable y viable bajo un escenario multi-específico y mega-diverso.

Palabras clave: gestión, licencias de pesca, pesquería demersal, dinámica pesquera, Brasil.

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INTRODUCTION

Licensing of fishing vessels is one of the several tools used by governmental authorities under the fishing regulation process. In some instances, it might represent only a bureaucratic step aiming at registering the units engaged in the fishery for statistical or control purposes (Pope, 2005). On the other hand, it may stand also for a key mechanism to limiting access (or to grant rights), to fishing grounds, and resources (Charles, 2005). If properly enforced, in combination with catch, effort and/or technical measures, (*e.g.*, Doulman, 1987; Harte & Barton, 2007; Havice, 2010), generates government revenues and/or contribute for the biological and socioeconomic sustainability of marine fisheries (Charles, 2005; Pope, 2005; but see Pearse, 1981 for a discussion on the inefficacy of licensing as a tool for controlling fleet capacity, and Fahy (2008) and Shen & Heino (2014), for examples of enforcement limitations).

In Brazil, license requirement for fishing vessels have appeared in federal regulations at least since the Fishing Code of 1938 (Brasil, 1938), substituted in 1967 by the Decree-Law 221/67 (Brasil, 1967) and, more recently, by the Fishing Law of 2009 (Brasil, 2009). All commercial fishing vessels, regardless whether artisanal or industrial, are required to have a license. Licenses are discretionary, precarious, individual, non-transferable and subjected to a quasi-automatic annual renewal if payment of a small tax and complying with some other legal requisites are proven (*e.g.*, regularity with "PREPS", the national vessel monitoring system program, which is obligatory for all industrial vessels and part of the artisanal fleets).

In spite of appearing in the 1950's, the Brazilian industrial fishery developed significantly only from the 1960s on, fueled by intensive governmental financial incentives provided under the Decree-Law of 1967 (Diegues, 1983). The southeastern-south region is a large marine fishing management area (extending from 18º20'S to the Brazilian border with Uruguay), where most of the country's industrial fisheries concentrates. Fleets were originally directed to a few target-species, defined as such by their production (*i.e.*, sardine *Sardinella brasiliensis*, caught by purse seiners), acceptance in the internal market (*i.e.*, scienid fishes, targeted by stern and pair trawlers), or high intrinsic economic value (*i.e.*, shrimps, exploited by side trawlers until 1968-1969, when they were converted to double-rig trawlers) (Valentini & Pezzuto, 2006).

At first, the industrial shrimp fishery operating in the southeastern-south Brazil targeted only the valuable pink-shrimps *Farfantepenaeus paulensis* and *F. brasiliensis*, caught in shelf bottoms between 30 and 80 m depth. The number of vessels in this fleet increased dramatically from nearly 75 units in 1966 to more than 400 in 1972. As a consequence of this huge increment in fishing effort, shrimp yields and fleet size declined rapidly thereafter and the stocks were successively diagnosed as overexploited since 1973 (Valentini *et al.*, 1991, 2012; D'Incao *et al.*, 2002; Ministério do Meio Ambiente, 2004). Simultaneously, an additional industrial fleet aiming at the sea-bob shrimp *Xiphopenaeus kroyeri* (hitherto exploited only by artisanal fishers up to 30 m depth) also developed, motivated by the reduction in pink-shrimp yields and increasing in sea-bob shrimp prices in the international market (Valentini & Pezzuto, 2006). After peaking at 15,591 ton in 1981, landings of this species declined to only 5,495 ton in 1999 (D'Incao *et al.*, 2002). Since 2004, the species has been officially recognized as at risk of overexploitation (Ministério do Meio Ambiente, 2004).

The scenario of the pink-shrimp fishery worsened after 1985, when the fleet size increased again to nearly 400 units (D'Incao *et al.*, 2002; Valentini & Pezzuto, 2006). Additionally, in the same year, a third double-rig fleet started to operate in Santa Catarina and Rio Grande do Sul states (Southern Brazil), focusing mostly on the coastal Argentine stiletto shrimp *Artemesia longinaris* (Bate) and Argentine red shrimp *Pleoticus muelleri* (Bate), flatfishes (*Paralichthys patagonicus* Jordan) and angel sharks (*Squatina* spp.) (Haimovici, 1998).

During the 1980's and the following decades, the two first double-rig fleets showed a progressive diversification in their dynamics. Two compensatory strategies were established to overcome the pink and sea-bob shrimp overexploitation: (1) to retain and focus on several other fishes and invertebrates caught as by-catch of traditional resources (Kotas, 1998; Perez & Pezzuto, 1998; Perez *et al.*, 2001, 2007; Tomás & Cordeiro, 2007; Tomás *et al.*, 2007); and (2), by expanding fishing areas to the outer shelf and slope, where new valuable targets and by-catches, started to be exploited (Perez *et al.*, 2001; Perez & Pezzuto, 2006). The two strategies, allied to the poor selectivity of the bottom trawling have made the double-rig fisheries in the region to be largely multi-specific. In fact, the number of commercial categories of fishes and invertebrates landed by the combined double-rig fleets in Santa Catarina state during 2012 surpassed 82 items, several of them comprising more than a single species (*e.g.,* the generic denomination "sharks") (UNIVALI/CTTMar, 2013).

Not only had the fleet dynamics of the double-rig fleets changed with time in the region. Licensing also showed significant modifications, this might be separated in three main phases. The first, encompassed the beginning of the industrial shrimp fisheries until the early 2000s, when licenses were defined under a monospecific perspective. Vessels were permitted to catch pink and sea-bob shrimps with their respective "incidental catches" (not specifically referred in the respective licenses). However, the importance of the latter increased with time at the same rate that the abundance of the targets declined. Because vessels, authorized to catch shrimps, expanded their operations to new areas and/or resources, and many other trawlers (new or converted from other fisheries) were unsuccessful to get shrimp licenses as their distribution was legally closed. Fishing authorities were pushed politically to accommodate both situations. License characteristics started, then, to become more flexible. At the same time that some licenses remained unchanged, in content, others became progressively more generic and embracing, up to a point where some of them allowed the exploitation, in the whole southeastern-south region, of "fishes, crustaceans and mollusks in general, excluding resources under control" (*i.e.,* excluding species for which new licenses were not available, as the pink-shrimp). Considering the large area of operation permitted, including the traditional sea-bob and pink-shrimp fishing grounds, the poor selectivity of the fishing method and the variety of licenses in force, this system enabled the operation of the double-rig vessels in any area, at any time and on any species (including resources under control, supposedly caught as by-catch). It represents nothing less than a disguise of an open-access regime (Valentini & Pezzuto, 2006).

After severe criticism and aiming at reorganizing the licensing process, in 2011 the Brazilian Ministry of Fisheries and Aquaculture launched a new licensing system (Brasil, 2011), to which all fishing vessels should adhere. Licenses were standardized and formally defined according to five criteria: a) fishing method, b) target species, c) incidental catches of marketable species, d) incidental catches of not marketable species whether due to legal, economic, or other constraints; and e) area of operation permitted. Scientific and vernacular names for the species listed in criteria b), c), and d) above, are formally included in the authorizations.

In this new system, licenses that were previously quite generic turned to be extremely specific and detailed, paradoxically, trying to accommodate the multi-specific feature of the current fisheries through the definition of a long and partially different list of species in each type of authorization. Given the high marine biodiversity of the southeastern-south Brazilian region (see Fig. 9 in Miloslavich *et al.,* 2011) and considering the unselective character of the double-rig bottom trawling fisheries, this change posed new challenges to the management and to the fishing industry as a whole.

Therefore, this paper aims at examining the behavior of the three most important industrial double-rig fleets operating in southeastern-south region of Brazil, as viewed from landings monitored in Santa Catarina harbors between 2008 and 2010. The landings of each fleet was analyzed and confronted with the criteria set out in the new licensing system, in order to verify to what extent this system suit to current fishing reality.

MATERIALS AND METHODS

As information of individual fishing licenses was not made available to the public by the Brazilian government until very recently, the Syndicate of Ship-owners and Fishing Industries of Itajaí and Region (SINDIPI) and Syndicate of Fishing Industry of Florianópolis (SINDIFLORIPA) kindly provided us with copies of licenses of all 234 double-rig vessels of their affiliated members. Nearly all industrial vessels based on Santa Catarina State are associated to one of these syndicates and they represent a significant part of the industrial double-rig fleet operating in southeastern-south region (*i.e.,* 80.7%, 51.3%, and 74.0% of the total number of vessels licensed, respectively, to catch demersal fishes, pink and sea-bob shrimps). Licenses were used to discriminate vessels according to the new licensing system (Table 1), and also to identify and retrieve the corresponding landing information stored in Santa Catarina Industrial Fishing Statistics Program database. This program is conducted by the University of Vale do Itajaí since 2000 and monitors landed catch (composition, weight, and ex-vessel prices), effort, and fishing areas of all industrial fleets which operate in Santa Catarina harbors through logbooks, sales records, and skippers' interviews. Quite frequently, vessels based on other states use local harbors for landing, but their data were not considered in this study, because the respective licenses were not known. From the 234 vessels affiliated to the syndicates, 191 landed in Santa Catarina during the study period.

Vessels authorized to fish pink-shrimp were separated according to the method of catch storage on board (crushed ice or cold chambers-*freezers*), as SINDIPI's technical staff suggested that they could have different operational characteristics (*e.g.*, days at the sea), influencing the respective catch composition. Data on total length and power of the main engine were obtained from licenses and used to provide basic physical characteristics of the fleets.

Table 1. Authorizations, according to the current license system, for industrial double-rig vessels operating in the shelf areas of the southeastern-south (SE-S) region. "Complementary authorization" refers to a temporary license granted to the fleet during the annual pink-shrimp fishery closure (March to May) for operations in areas outside the main target distribution.

Authorization	Target species	Expected by-catch	Area of operation
Pink-shrimp	Pink-shrimp, Argentine red shrimp and Argentine stiletto shrimp	Argentine conger, Argentine croaker, Argentine goatfish, Argentine hake, Atlantic bigeye, blue runner, Brazilian codling, Brazilian flathead, comb grouper, common octopus, crab, dogfish, flatfish, grey triggerfish, Jamaica weakfish, king weakfish, lane snappers, largehead hairtail, monkfish, namorado sandperch, pink cusk-eel, rays, red grouper, red porgy, rough scad, sea trout, slipper lobster, snappers, snowy grouper, southern searobin, squid, striped weakfish, tile fish, Uruguayan lobster, whitemouth croaker	Territorial sea SE-S; and EEZ SE-S (complementary authorization: outside the pink-shrimp area - above 100 m)
Sea-bob shrimp	Sea-bob shrimp, Argentine red shrimp and Argentine stiletto shrimp	Argentine croaker, Argentine goatfish, banded croaker, bluewing searobin, Brazilian codling, crabs, dogfish, flatfish, grey triggerfish, Jamaica weakfish, king weakfish, monkfish, rays, sea trout, southern kingcroaker, southern white shrimp, squid, striped weakfish, whitemouth croaker	Territorial sea SE-S; and EEZ SE-S
Demersal fish	Whitemouth croaker, Argentine croaker, sea trout and king weakfish, flatfish, Brazilian codling, bluewing searobin	Argentine conger, Argentine goatfish, Atlantic bigeye, banded croaker, blue runner, Brazilian flathead, comb grouper, croakers, drums, Jamaica weakfish, lane snappers, largehead hairtail, monkfish, namorado sandperch, pink cusk-eel, rays, red grouper, red porgy, slipper lobster, snappers, snowy grouper, southern kingcroaker, squid, striped weakfish, tile fish, Uruguayan lobster	Territorial sea SE-S and EEZ SE-S (depths less than 250 m)

Spatial distribution of the total fishing effort was also analyzed for each fleet. Firstly, fishing areas visited in each trip, as informed by the skippers during interviews or pointed out in the respective log books were ascribed to a 30'x30' grid. More than a single quadrant could be assigned, as more than frequently a same trip covered several quadrants (*i.e.*, fishing grounds extended for very large areas along the shelf). The total number of trips recorded by quadrant during the whole study period was then calculated and mapped for each fleet.

Two main analyses were conducted from landing data: a) catch was examined in terms of weight and revenue per biological species/commercial categories and b) catch was broken down into the categories "target-species" and "expected by-catch", as defined in the respective licenses (Table 1). Landed items not listed in the authorizations were classified as "others". Correspondence between vernacular and scientific names of all species mentioned in this paper can be found in Table 2.

The proportion by weight and by revenue, measured in Brazilian currency, (Reais R$, conversion rate of US$1.00 = R$1.70 in December 1st, 2010) that each item accounted for, in relation to the total landings of each fleet, was calculated per year, and for the whole study period, to investigate their role in the maintenance of the respective fishing fleets.

To enable proper comparison of revenues, along the three studied years, monthly mean prices (US$/kg) of each species were corrected for inflation to the reference date of December 2010. The Producer Price Index (PPI) (Índice de Preços ao Produtor Amplo-Fundação Getúlio Vargas, 2012), which records the monthly variation of prices of agricultural and industrial goods at the producer level, *i.e.* before final marketing, was used. Mean ex-vessel price (Price - US$/kg) of the species/commercial category i in the month/year j was, standardized as follows:

$$Corrected\ price_{ij} = Price_{ij} \times \left(\frac{PPI_{December2010}}{PPI_j} \right)$$

RESULTS

Fleet characteristics

A total of 2,617 trips and 46,711 ton were monitored in the study period. From the 191 vessels analyzed, 68

Table 2. Vernacular and scientific names of the species landed and/or listed in the licenses of the industrial double-rig fleets of Santa Catarina State, southern Brazil.

Vernacular name	Scientific name	Family
Angel sharks	*Squatina* spp.	Squatinidae
Argentine conger	*Conger orbignianus*, *Myrophis punctatus*, *Raneya brasiliensis*	Congridae Ophichthidae Ophidiidae
Argentine croaker	*Umbrina canosai*	Sciaenidae
Argentine goatfish	*Mullus argentinae*	Mullidae
Argentine hake	*Merluccius hubbsi*	Phycidae
Argentine red shrimp	*Pleoticus muelleri*	Penaeidae
Argentine stiletto shrimp	*Artemesia longinaris*	Penaeidae
Atlantic bigeye	*Priacanthus arenatus*	Priacantidae
Banded croaker	*Paralonchurus brasiliensis*	Sciaenidae
Blue runner	*Caranx crysos*	Carangidae
Bluewing searobin	*Prionotus punctatus*	Triglidae
Brazilian codling	*Urophycis brasiliensis*	Phycidae
Brazilian flathead	*Percophis brasiliensis*	Percophidae
Codling	*Urophycis mystacea*	Phycidae
Comb grouper	*Mycteroperca bonaci*, *M. microlepis*, *M. acutirostris*	Serranidae
Common octopus	*Octopus vulgaris*	Octopodidae
Crab	*Callinectes sapidus*, *C. bocourti*, *C. danae*, *C. ornatus*	Portunidae
Croakers	*Stellifer brasiliensis*; *S. rastrifer*; *S. naso*	Sciaenidae
Dogfishs	*Prionace glauca*, *Carcharhinus falciformis*, *Isurus oxyrinchus,* *Squalus acanthias*, *S. cubensis*, *S. blainville*, *Mustelus fasciatus*	Carcharhinidae Lamnidae Squalidae Triakidae
Drums	*Cynoscion acoupa*, *C. leiarchus*, *C. guatucupa*, *Larimus breviceps*, *Pogonias cromis*	Sciaenidae
Flatfish	*Paralichthys brasiliensis*, *P. patagonicus*	Paralichthydae
Grey triggerfish	*Balistes capriscus*	Balistidae
Jamaica weakfish	*Cynoscion jamaicensis*	Sciaenidae
King weakfish	*Macrodon ancylodon*	Sciaenidae
Largehead hairtail	*Trichiurus lepturus*	Trichiuridae
Monkfish	*Lophius gastrophysus*	Lophiidae
Namorado sandperch	*Pseudopercis numida*	Mugiloididae
Pink cusk-eel	*Genypterus brasiliensis*	Ophidiidae
Pink-shrimp	*Farfantepenaeus paulensis*, *F. brasiliensis*	Penaeidae
Rays	*Atlantoraja cyclophora*, *A.castelnaui; Rioraja agassizii*, *Breviraja spinosa*, *Rajella purpuriventralis*	Rajidae
Red grouper	*Epinephelus morio*	Serranidae
Red porgy	*Pagrus pagrus*	Sparidae
Rough scad	*Trachurus lathami*	Carangidae
Sand flounder	*Paralichthys isósceles*, *P. triocellatus*	Paralichthydae
Sea trout	*Cynoscion* spp.	Sciaenidae
Sea-bob shrimp	*Xiphopenaeus kroyeri*	Penaeidae
Skate raja	*Atlantoraja platana*, *Sympterygia bonapartii*, *S. acuta*	Rajidae
Slipper lobster	*Scyllarides deceptor*, *S. brasiliensis*, *S. delfosi*	Scyllaridae
Snappers	*Lutjanus cyanopterus*, *L. jocu*, *L. synagris*, *Ocyurus chrysurus*, *Rhomboplites aurorubens*	Lutjanidae
Snowy grouper	*Epinephelus niveatus*, *E. morio*	Serranidae
Southern kingcroaker	*Menticirrhus* spp.	Sciaenidae
Southern white shrimp	*Litopenaeus schimitti*	Penaeidae
Spiny dogfish	*Squalus* spp.	Squalidae
Squid	*Loligo plei*, *L. sanpaulensis*	Loliginida
Striped soldier shrimp	*Plesionika edwardsii*	Pandalidae
Striped weakfish	*Cynoscion striatus*	Sciaenidae
Tile fish	*Lopholatilus villarii*	Branchiostegidae
Uruguayan lobster	*Metanephrops rubellus*	Nephropidae
Whitemouth croaker	*Micropogonias furnieri*	Sciaenidae

were licensed for pink-shrimp. They used crushed ice as catch conservation method (hereafter referred to as pink-shrimp icing vessels). Sea-bob shrimp and demersal fish fleets totalized 47 and 44 units, respectively. Only 32 pink-shrimp vessels were equipped with cold chambers (pink-shrimp freezers; Table 3). The demersal fish fleet showed mean yields/trip much higher than those exhibited by the other vessels and accounted for 54.5% of the total landings. Excepting for the number of trips which reduced from 2008 to 2010 in all fleets, the other variables did not show important changes in the period (Table 3).

As revealed by Kruskal-Wallis tests, the fleets differed both in their median lengths (H = 114.7; N = 192; $P < 0.0001$) and engine power (H = 101.9; N = 190; $P < 0.0001$). A post-hoc test showed that vessels targeting sea-bob shrimp were the smallest (median total length = 14.8 m) as compared to the other fleets ($P < 0.0001$). Pink shrimp freezers and vessels targeting demersal fishes on the other hand did not show differences among them ($P = 0.96$) but were bigger than the other vessels ($P < 0.01$). The same results were found when contrasting median engine power among the fleets. In this case, differences among pink shrimp freezers + demersal fish vessels and the other fleets were even more significant ($P < 0.001$) (Table 4).

As previously suspected, the use of crushed ice instead of cold chambers limits the permanence of the vessels at the sea. On average, fishing trips of pink-shrimp icing vessels lasted only 18.5 days, contrasting with the 34.5 days spent by the pink-shrimp freezer fleet (Table 5). Haul duration and number of hauls per day differed also between the two pink-shrimp fleets, freezers conducting less and longer hauls per day. Sea-bob shrimp vessels showed the lowest autonomy among the four fleets spending, on average, 17 days at sea. Their hauls were also the shortest (mean = 4.0 h), resulting in a higher number of tows per day (Table 5).

Spatial distribution of fishing effort

Freezers operate from north of Vitoria to the border with Uruguay, mostly in fishing grounds shallower than 100 m. However, areas between 100 and 200 m deep or even down to the slope were also exploited, mainly between Santos e Itajaí harbors. The area between Itajaí and Paranaguá concentrated the highest number of trips per quadrant (Fig. 1a). Effort of the pink-shrimp icing fleet was much more spread, occupying all the continental shelf and upper slope from Rio de Janeiro to the border with Uruguay. Trips concentrated in two main areas: towards the north of Itajaí, between 50 and 100-200 m isobaths, and towards the south of the same harbor, in shallower waters (Fig. 1b). The sea-bob shrimp fleet showed also a continuous occupation of the continental shelf, though rarely exceeding 100 m deep. In fact, most of the trips concentrated in very coastal areas below 50 or even 25 m deep, especially between Cananéia and Santos harbors. This fleet rarely, if ever, operated on slope grounds (Fig. 1c). Spreading its fishing effort essentially throughout the same areas where pink-shrimp icing vessels operate, demersal fish fleet exploited two main fishing grounds: the first, situated along the outer shelf and slope between Santos and Laguna and the second, on the inner shelf from Laguna towards the southern end of the study area (Fig. 1d).

Catch composition per species or category

From the main resources landed by the double-rig fleets in Santa Catarina, the pink-shrimp stands out as the most valuable, with mean prices per kilogram exceeding twice the southern white shrimp, which ranked second on the price scale (Table 6). Complement the "top ten" items in terms of intrinsic value other three shrimps: the Uruguayan lobster, squid and flatfish, all species exploited on the continental shelf, and the monkfish and codling caught on the slope (Table 6). Although price fluctuations had been noticed throughout the study period, no definite pattern was observed. Whereas the price of pink and Argentine stiletto shrimps decreased from 2008 to 2010, other species showed continuous appreciation in the same period (*e.g.,* Uruguayan lobster) or were valued differently in each year (Table 6).

Examining the catch composition per fleet revealed some distinct patterns among them. The pink-shrimp freezers landed 56 species/categories, but only ten accounted for over 81% of the total weight and 96% of revenue (Table 7). The fleet showed to be essentially shellfish-oriented as four shrimp species, the squid and the Uruguayan lobster comprised six out of the ten main items landed in terms of value, with the pink-shrimp demonstrating, by far, the largest importance. Mixture (a multi-species assortment of items of low individual value) amounted 19% of the total weight, a value very close to the pink-shrimp contribution (22%). Landings totalized 2,154 ton and more than US$10 million in the study period.

Pink-shrimp icing vessels showed a more diversified pattern, as 68 species/categories were landed and 13 of them were necessary to generate, respectively, 82 and 90% of the landed weight and revenue monitored in the period (Table 8). While revenues from the pink-shrimp summed 77% in freezer vessels, its importance decreased to 35% in the icing fleet (corresponding to only 4% of the landed weight), with other shrimps increasing their participation in the

Table 3. Temporal variation in number of vessels, number of trips, total landed catch (ton), and mean catch rate (ton/trip) of the industrial double-rig fleets of Santa Catarina State, Southern Brazil, as recorded by the Santa Catarina Industrial Fishing Statistics Program. Pink-shrimp vessels were separated according to the catch storage method.

Fleet	Period															
	2008				2009				2010				Total			
	Vessels	Trips	Landings (ton)	ton/trip	Vessels	Trips	Landings (ton)	ton/trip	Vessels	Trips	Landings (ton)	ton/trip	Vessels	Trips	Landings (ton)	ton/trip
Pink-shrimp (total)	85	444	5,040.4	11.4	89	417	5,011.5	12.0	81	355	3,631.6	10.2	100	1,216	13,683.5	11.3
Pink-shrimp freezer	27	107	883.3	8.3	25	85	740.8	8.7	23	63	529.7	8.4	32	255	2,153.8	8.4
Pink-shrimp icing	58	337	4,157.2	12.3	64	332	4,270.7	12.9	58	292	3,101.9	10.6	68	961	11,529.8	12.0
Sea-bob shrimp	39	232	3,003.4	12.9	43	176	2,126.1	12.1	43	214	2,419.5	11.3	47	622	7,549.0	12.1
Demersal fishes	39	287	9,063.9	31.6	37	242	7,835.3	32.4	37	250	8,579.4	34.3	44	779	25,478.7	32.7
Total	163	963	17,107.8	17.8	169	835	14,973.0	17.9	161	819	14,631	17.9	191	2,617	46,711.3	17.8

Table 4. Total length (m) and main engine power (HP) of the industrial double-rig fleets of Santa Catarina State, southern Brazil. Values are medians (minimum-maximum). Pink-shrimp vessels were separated according to the catch storage method.

Fleet	Total length (m)	Main engine power (HP)
Pink-shrimp freezer	21.9 (17.9 - 22.5)	325 (170 - 425)
Pink-shrimp icing	18.4 (13.2 - 24.2)	227.5 (110 - 425)
Sea-bob shrimp	14.6 (10.5 - 18.3)	130 (90 - 325)
Demersal fishes	22.1 (17.6 - 24.8)	325 (175 - 425)

fleet economy. The Argentine stiletto shrimp and mixture were the most abundant items in the landings. Fleet's revenues and landed weight exceeded US$22 million and 11,500 ton in the study period, respectively.

Among 50 species/categories recorded, only seven of them provided 95% of the landings and revenues for the sea-bob shrimp fleet (Table 9). In spite of being traditionally the fleet's main target, landed weight and revenue obtained from the sea-bob shrimp figured below the Argentine stiletto shrimp, whose landings accounted for 50% of the total. Conversely, given its lower individual price as compared to the sea-bob shrimp (Table 6), the contribution of the Argentine stiletto shrimp in the total revenue was only marginally superior. The Argentine red shrimp, which is caught in association with the latter species in coastal fishing grounds southwards from the main sea-bob shrimp area of distribution, showed also significant importance, accounting for 11% of the volume and 20% of the revenue in the period. These two southern shrimps, therefore, revealed to play a key role in the current dynamics of the sea-bob shrimp fleet, whose total landings in the period attained 7,549 ton and US$12.1 million (Table 9).

As expected, fishes were the main items caught by the demersal fishes fleet, with nine species plus the "not discriminated" category accounting for over 77% of the weight and 81% of the revenue (Table 10). Among the 68 species/categories landed, codling, flatfish, Argentine hake, and bluewing searobin were dominant in both criteria. In spite of contributing with only 7% of the landed weight, flatfishes corresponded to 18% of the total fleet's revenues (US$29.6 million), given its high individual value (US$3.09 kg^{-1}) as compared to the other three species (*e.g.*, codling - US$1.26 kg^{-1}) (Tables 6-10).

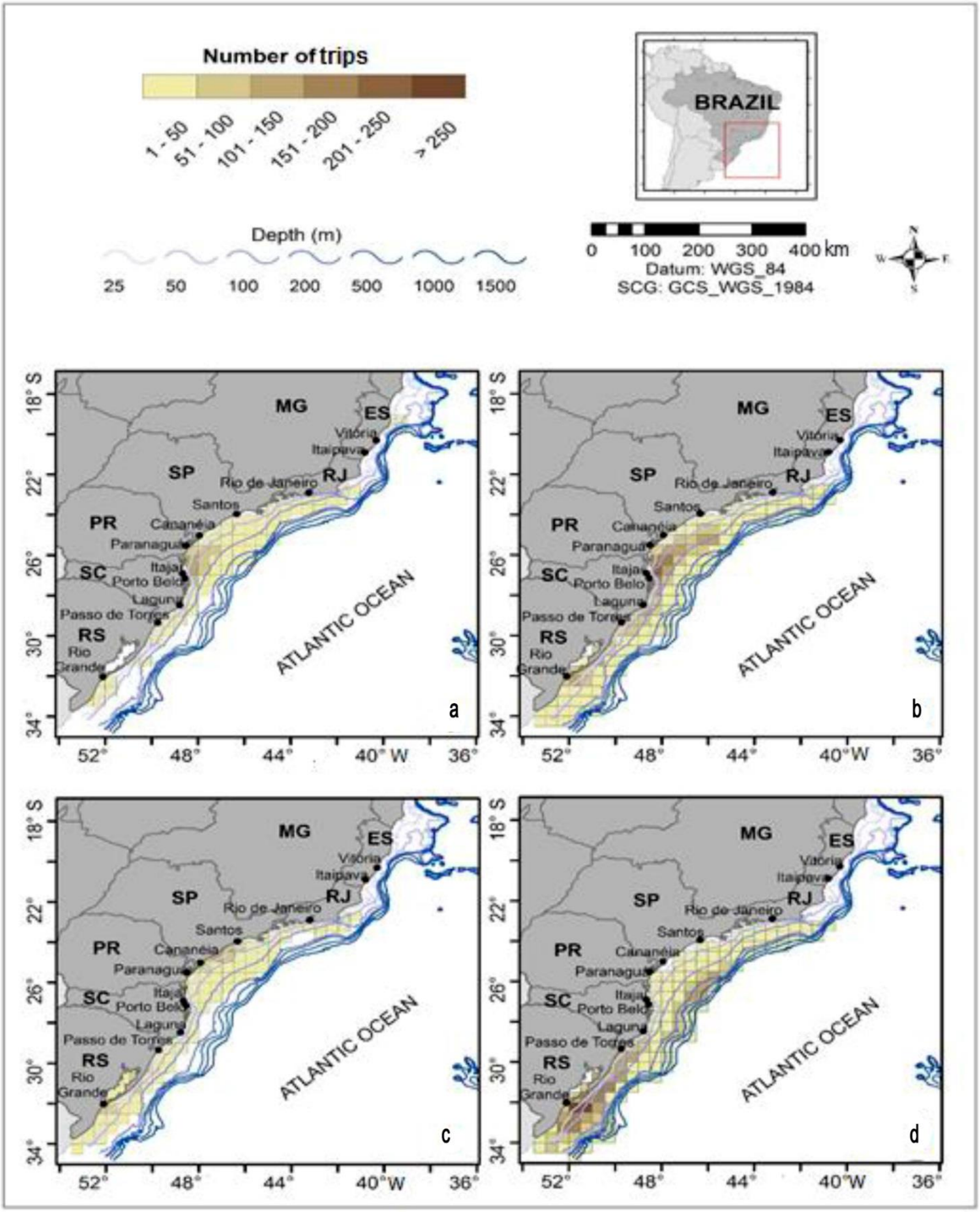

Figure 1. Spatial distribution of fishing effort (number of trips) of the four industrial double-rig fleets of Santa Catarina State, southern Brazil, monitored between 2008 and 2010 and licensed for: a: pink-shrimp, equipped with cold chambers (freezer), b: pink-shrimp using crushed ice, c: sea-bob shrimp and d: demersal fishes. Main fishing harbors are indicated. ES, MG, RJ, SP, PR, SC and RS refer, respectively, to the Brazilian states of Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul.

Table 5. Operational characteristics the industrial double-rig fleets of Santa Catarina State, southern Brazil. Values are medians (minimum-maximum), except for number of trips. Pink-shrimp vessels were separated according to the catch storage method.

Fleet	Number of trips	Days at sea	Days at fishing	Hauls/Day	Haul duration (h)
Pink-shrimp freezer	216	34.5 (3-60)	26 (3-50)	4 (2-7)	5.5 (1.8-8)
Pink-shrimp icing	875	18.5 (6-36)	15 (3-33)	5 (2-8)	4.5 (2-7)
Sea-bob shrimp	464	17 (7-30)	14 (3-27)	5 (3-10)	4.0 (2-6)
Demersal fishes	714	24 (6-30)	18 (3-30)	4 (2-6)	4.7 (2.5-6.5)

Table 6. Mean ex-vessel prices of the main fishery resources exploited by the industrial double-rig fleets of Santa Catarina State, southern Brazil. All prices are in Brazilian currency (US$/kg) and were standardized to the reference date of December 2010. SD: standard deviation, Not discriminated: items whose composition was unknown, Mixture: a specific item of the landings composed by low-valued species landed and sold on an aggregated basis.

Species or commercial categories	Year						Mean
	2008		2009		2010		
	Mean	SD	Mean	SD	Mean	SD	
Pink-shrimp	19.71	0.79	15.44	2.25	14.98	0.85	16.71
Southern white shrimp	7.70	1.41	9.26	0.49	-		8.48
Uruguayan lobster	4.50	1.30	6.71	1.76	8.52	0.00	6.58
Argentine red shrimp	3.17	0.38	3.08	0.66	3.46	0.14	3.24
Flatfishh	3.18	0.58	3.26	0.62	2.84	0.25	3.09
Striped soldier shrimp	2.84	0.17	2.59	0.35	-		2.72
Squid	0.99	0.62	2.21	1.28	2.82	0.21	2.01
Sea-bob shrimp	1.90	0.09	1.60	0.33	1.99	0.15	1.83
Monkfish	1.34	0.15	1.47	0.19	1.55	0.34	1.45
Not discriminated	1.39	0.06	1.29	0.06	1.27	0.04	1.32
Codling	1.19	0.06	1.33	0.16	-		1.26
Argentine stiletto shrimp	1.39	0.28	1.37	0.36	0.94	0.09	1.23
Brazilian codling	1.00	0.17	1.09	0.09	0.86	0.09	0.98
Sand flounder	0.88	0.10	1.10	0.14	0.72	0.05	0.90
Bluewing searobin	0.82	0.04	0.81	0.12	0.82	0.08	0.82
Argentine hake	0.78	0.13	0.84	0.08	0.79	0.15	0.80
Striped weakfish	0.78	0.12	0.81	0.07	0.73	0.15	0.78
Dogfishs	0.54	0.00	1.00	0.00	-		0.77
Skate raja	0.74	0.03	0.74	0.09	0.75	0.12	0.74
Grey triggerfish	0.74	0.13	0.69	0.08	0.71	0.05	0.72
Mixture	0.40	0.02	0.45	0.06	0.46	0.08	0.44

Catch composition according to the license system

In the pink-shrimp freezer fleet, nearly 80% of revenues were obtained from the target-species (as defined in the respective licenses), in spite of their very small participation in terms of volume (Fig. 2). This difference is explained by the predominance of the valuable pink-shrimp in the landings, mostly when compared to the two other possible targets (*i.e.,* Argentine red and stiletto shrimps), whose amount and individual prices were significantly lower (Tables 6, 7). In terms of weight, the most important category was the "expected by-catch" which attained, in 2010, nearly 50% of the total landings. Species not listed in the licenses had also a significant participation in terms of weight, in spite of representing less than 5% of the revenues (Fig. 2).

Targets were also the main items for the economic sustainability of the pink-shrimp icing fleet, even considering that their importance in the total revenue declined to *ca.* 60%. Considering the whole study period,

Table 7. Weight (ton) and revenue (US$) of the main items landed between 2008 and 2010 in Santa Catarina State by the local industrial fleet licensed to catch pink-shrimps. Only vessels that use cold chambers (freezers) to conserve the catch aboard were considered. Prices were standardized to the reference date of December 2010. Mixture: a specific item of the landings composed by low-valued species landed and sold on an aggregated basis.

Species or commercial categories	Year						Total			
	2008		2009		2010					
	ton	US$	ton	US$	ton	US$	ton	%	US$	%
Pink-shrimp	174	3,432,559	192	2,898,560	100	1,530,971	465	22	7,862,089	77
Squid	43	44,641	44	154,116	124	365,105	211	10	563,862	6
Uruguayan lobster	25	135,619	19	145,334	14	121,700	58	3	402,654	4
Codling	69	84,101	52	75,767	37	44,718	157	7	204,587	2
Mixture	135	54,502	179	83,211	94	47,972	407	19	185,685	2
Brazilian codling	75	82,840	41	42,739	26	22,709	142	7	148,288	1
Striped soldier shrimp	33	90,368	9	25,237	6	15,168	48	2	130,773	1
Bluewing searobin	43	35,592	73	60,148	16	12,927	132	6	108,667	1
Argentine stiletto shrimp	71	82,562	-	-	26	22,165	97	4	104,726	1
Argentine red shrimp	28	84,074	0	824	3	8,640	31	1	93,539	1
Total	883	4,327,060	741	3,617,671	530	2,280,568	2,154	81	10,225,299	96

Table 8. Weight (ton) and revenue (US$) of the main items landed between 2008 and 2010 in Santa Catarina state by the local industrial fleet licensed to catch pink-shrimps. Only vessels that use crushed ice to conserve the catch aboard were considered. Prices were standardized to the reference date of December 2010. Mixture: a specific item of the landings composed by low-valued species landed and sold on an aggregated basis.

Species or commercial categories	Year						Total			
	2008		2009		2010					
	ton	US$	ton	US$	ton	US$	ton	%	US$	%
Pink-shrimp	130	2,559,972	229	3,311,348	125	1,907,278	484	4	7,778,598	35
Argentine stiletto shrimp	1,252	1,520,070	1,138	1,328,928	888	836,791	3,278	28	3,685,789	16
Argentine red shrimp	483	1,527,166	297	764,166	48	166,03	828	7	2,457,362	11
Flatfish	159	508,721	167	546,255	81	229,234	407	4	1,284,210	6
Uruguayan lobster	35	180,962	55	341,837	37	312,784	127	1	835,583	4
Codling	194	229,662	195	256,392	189	221,095	578	5	707,149	3
Bluewing searobin	367	302,219	296	238,004	125	95,335	788	7	635,559	3
Striped soldier shrimp	53	147,063	29	74,082	156	380,081	238	2	601,226	3
Mixture	309	124,691	576	258,555	427	204,342	1,312	11	587,588	3
Squid	27	18,589	14	46,478	136	385,116	177	2	450,183	2
Brazilian codling	191	195,203	202	219,699	73	62,751	466	4	477,653	2
Sand flounder	134	123,296	123	129,265	81	58,737	339	3	311,298	1
Skate raja	151	111,288	172	118,104	87	61,56	410	4	290,952	1
Total	4,157	8,326,331	4,271	8,382,214	3,102	5,684,868	11,530	82	22,393,414	90

targets and expected by-catch species had similar contribution in terms of weight, although different patterns had been observed from year to year. Nearly 20% of the landings corresponded to items not included in the licenses, but, as observed in the pink-shrimp freezer fleet, their input to the total revenue was small (Fig. 3).

Sea-bob shrimp fleet revealed totally reliant from the three shrimp listed as targets, as they represented nearly 90% of the respective landings and revenues. The remaining 10% were equally divided between the other two categories (Fig. 4). On the other hand, demersal fish vessels were sustained mostly by species not listed in their respective licenses as nearly 50% of the landings and revenue originate from their catches (Fig. 5). Targets contribution in weight and revenue varied between *ca.* 20 and 30% and between 30 and 40%, respectively, depending on the year. Compara-

Table 9. Weight (ton) and revenue (US$) of the main items landed between 2008 and 2010 in Santa Catarina State by the local industrial fleet licensed to catch sea-bob shrimp. Prices were standardized to the reference date of December 2010. Mixture: a specific item of the landings composed by low-valued species landed and sold on an aggregated basis.

Species or commercial categories	Year						Total			
	2008		2009		2010					
	ton	US$	ton	US$	ton	US$	ton	%	US$	%
Argentine stiletto shrimp	1,702	2,132,188	999	1,158,630	1,040	976,405	3,741	50	4,267,223	35
Sea-bob shrimp	501	964,036	596	868,721	1,124	2,240,375	2,221	29	4,073,132	34
Argentine red shrimp	525	1,643,487	229	634,611	60	206,578	814	11	2,484,676	20
Southern white shrimp	10	82,005	19	165,895	15	113,630	44	1	361,530	3
Mixture	80	45,318	113	191,369	66	50,962	259	3	287,649	1
Flatfish	11	31,102	6	51,164	8	30,448	24	0	112,714	1
Pink-shrimp	2	30,339	13	20,110	3	23,170	19	0	73,619	2
Total	3,003	5,131,339	2,126	3,233,821	2,419	3,817,836	7,549	94	12,182,997	96

Table 10. Weight (ton) and revenue (US$) of the main items landed between 2008 and 2010 in Santa Catarina State by the local industrial fleet licensed to catch demersal fishes. Prices were standardized to the reference date of December 2010. Not discriminated: items whose composition were unknown.

Species or commercial categories	Year						Total			
	2008		2009		2010					
	ton	US$	ton	US$	ton	US$	ton	%	US$	%
Codling	2,182	2,612,909	2,388	3,157,721	2,194	2,508,868	6,764	27	8,279,498	28
Flatfish	659	2,155,298	553	1,904,528	493	1,391,747	1,704	7	5,451,573	18
Argentine hake	894	716,485	1,210	1,053,460	961	753,176	3,065	12	2,523,120	8
Bluewing searobin	1,214	1,010,630	542	422,346	773	609,799	2,529	10	2,042,775	7
Monkfish	242	327,107	322	473,905	557	882,953	1,121	4	1,683,966	6
Brazilian codling	574	590,406	240	258,841	299	259,252	1,113	4	1,108,499	4
Not discriminated	386	612,561	131	203,615	122	161,347	638	3	977,523	3
Skate raja	378	308,059	327	231,558	358	255,777	1,064	4	795,394	3
Striped weakfish	296	213,553	216	174,155	277	204,784	790	3	592,492	2
Grey triggerfish	225	170,063	264	168,853	322	230,278	811	3	569,195	2
Total	9,064	10,723,166	7,835	9,981,431	8,579	8,959,541	25,479	77	29,664,139	81

tively, species listed as expected by-catch always a played smaller role for this fleet (Fig. 5).

Although differing as to the dependence on the categories “targets”, “expected by-catch”, and “others”, the four fleets presented a high percentage of coincidental species. Comparing the species listed in the three types of licenses, the percentage of coincidental items varied from a minimum of 31.8% between sea-bob shrimp and demersal fish fleets to a maximum of 71.1% between the latter and the pink-shrimp fleets (Table 11). When considering the landings actually performed between 2008 and 2010, the overlapping in catch composition increased significantly, reaching 82.4% between demersal fishes and pink-shrimp icers fleet (Table 11).

DISCUSSION

In force since 2011, the new Brazilian fishing licensing scheme has produced some beneficial outcomes, standardizing licenses, characteristics, and increasing the control and transparency in the system as a whole. However, the present results reveal that, at least concerning the bottom industrial double-rig fisheries, this system has not reverted neither the excessive effort and overlapping among fleets, nor the quite generalist access rights conferred by the preceding collection of non-standardized licenses which, among other negative consequences, posed the sustainability of the exploited demersal stocks on a high level of risk.

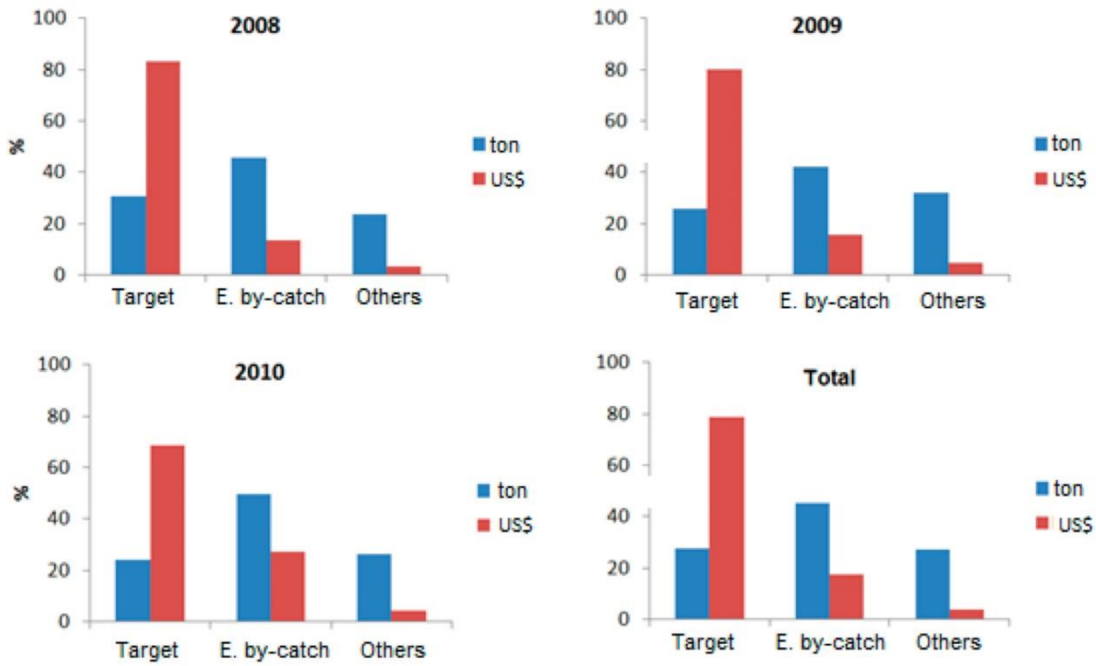

Figure 2. Contribution in weight (ton) and revenue (US$) of target and expected by-catch species as defined in the industrial double-rig pink-shrimp licenses, according to landings monitored in Santa Catarina State, between 2008 and 2010. "Other" refers to species not listed in the licenses. Only vessels using cold chambers (freezers) to conserve the catch aboard were considered.

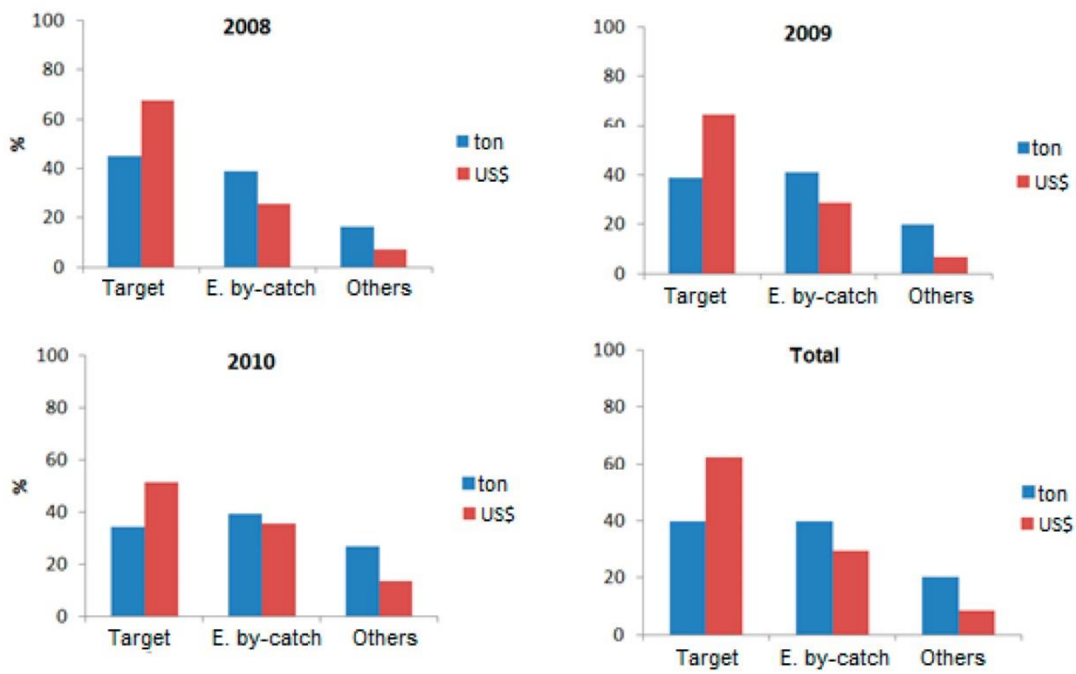

Figure 3. Contribution in weight (ton) and revenue (US$) of target and expected by-catch species as defined in the industrial double-rig pink-shrimp licenses, according to landings monitored in Santa Catarina State, between 2008 and 2010. "Other" refers to species not listed in the licenses. Only vessels using crushed ice to conserve the catch aboard were considered.

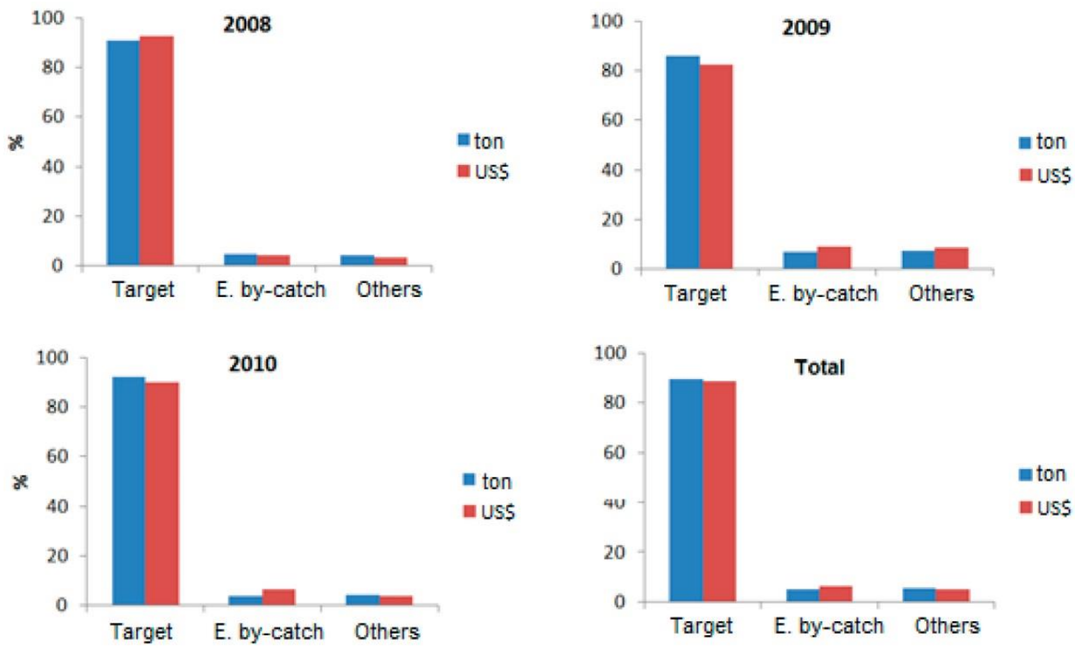

Figure 4. Contribution in weight (ton) and revenue (US$) of target and expected by-catch species as defined in the industrial double-rig sea-bob shrimp licenses, according to landings monitored in Santa Catarina State, between 2008 and 2010. "Other" refers to species not listed in the licenses.

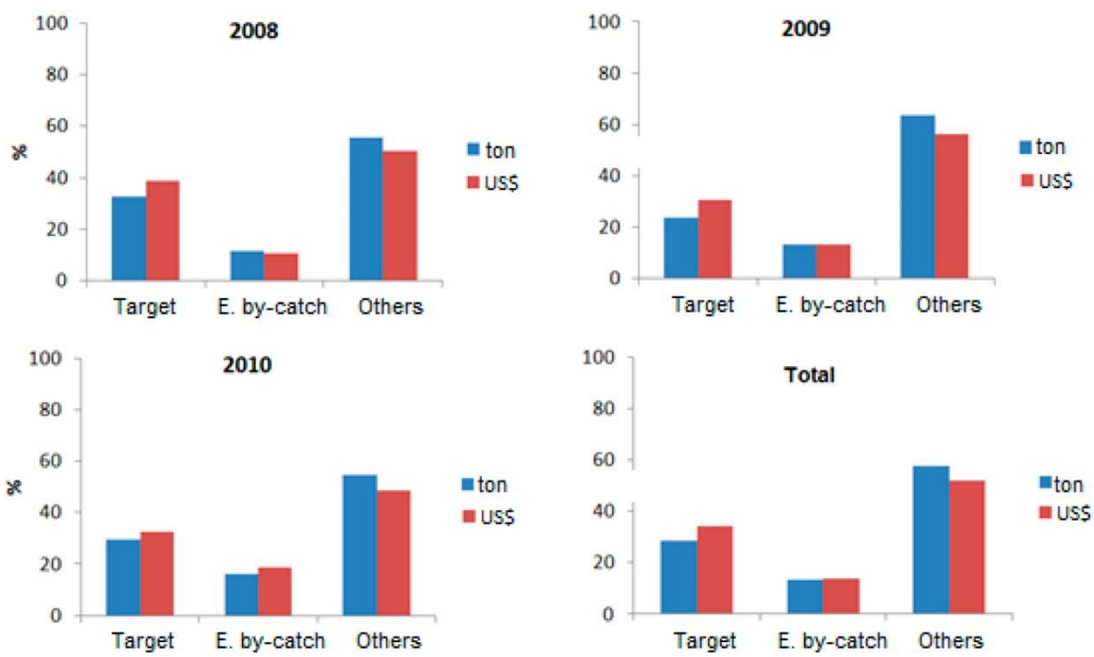

Figure 5. Contribution in weight (ton) and revenue (US$) of target and expected by-catch species as defined in the industrial double-rig demersal fishes licenses, according to landings monitored in Santa Catarina State, between 2008 and 2010. "Other" refers to species not listed in the licenses.

As demonstrated by Table 11, in spite of defining different targets (except by the Argentine red and stiletto shrimps, to be commented below), actually, a high proportion of species appear repeatedly in the three licenses examined. In combination with the same permitted fishing areas and with the absence of legally established limits for the proportion that target and predicted by-catch species can attain in landings of

Table 11. Percentage of species in common in licenses and landings of the industrial double-rig fleets of Santa Catarina State, Southern Brazil, monitored between 2008 and 2010. Pink-shrimp vessels were separated according to the catch storage method. Because licenses are the same for all pink-shrimp vessels regardless of their storage method, percentages were repeated in the table when comparing species listed in their respective licenses with the other fleets.

Fleet	Criteria							
	License				Landing			
	Pink-shrimp freezer	Pink-shrimp icing	Sea-bob shrimp	Demersal fishes	Pink-shrimp freezer	Pink-shrimp icing	Sea-bob shrimp	Demersal fishes
Pink-shrimp freezer	-	-	40.9	71.1	-	70.8	71.0	73.2
Pink-shrimp icing	-	-	40.9	71.1	70.8	-	71.0	82.4
Sea-bob shrimp	40.9	40.9	-	31.8	71.0	71.0	-	66.2
Demersal fishes	71.1	71.1	31.8	-	73.2	82.4	66.2	-

each fleet, this fact opens the possibility of vessels operate opportunistically over much the same resources, irrespective of their license type. The very high percentage of common species which were effectively landed by the different fleets during the study period confirms this (Table 11).

The inclusion of the Argentine red and stiletto shrimps as targets for all vessels pertaining both to the pink and sea-bob shrimp fleets illustrates the consequence of having species in common in different licenses. Directed catches of these species have increased mostly from the middle 1990’s on, when the overcapitalized pink-shrimp fleet based in Santa Catarina started to exploit them as compensatory resources, in addition to a small-scale fleet which was already present in Rio Grande do Sul. Such fact has originated an abundant and seasonal fishery conducted on inner shelf waters extending from Southern Santa Catarina towards the border between Brazil and Uruguay (Perez *et al*., 2001; D’Incao *et al*., 2002; Valentini & Pezzuto, 2006). Maximum Sustainable Yields (MSY) of these species were estimated for Brazilian waters only by Baptista-Metri (2007), and attained 4,447.3 ton yr^{-1} and 3,579.4 ton yr^{-1} for the Argentine red and stiletto shrimps, respectively. Whereas historical landings of the first species were always below the MSY, in the case of the stiletto shrimp, it was exceeded at least in 2000, 2003, 2004, 2008 and 2009 (Baptista-Metri, 2007; Benincá, 2013). Fishing effort directed to these shrimps has been considered excessive (Baptista-Metri, 2007; Dumont & D’Incao, 2008) and concerns about the risk of recruitment overfishing of the latter species were recently raised on a study by Dumont *et al.* (2011).

As compared to other shelf and slope bottom-trawl fisheries conducted on Southeastern-South Brazilian waters, which developed a progressive multi-specific behavior, the industrial sea-bob shrimp fishery maintained a mono-specific characteristic in terms of targets, at least up to late 1990's - early 2000's (Valentini & Pezzuto, 2006). In fact, Graça-Lopes *et al.* (2002a) studied the sea-bob shrimp industrial fleet which landed in São Paulo during 1988 and found by-catch species having a much lower importance than the target in the landings. Higher proportions of other species were found only in a few situations when the production of the sea-bob shrimp declined. The present paper shows, however, that multi-specificity is also emerging in this fleet as more than a half of the its landings and revenues originated from the Argentine red and stiletto shrimps, whereas the sea-bob shrimp contributed, respectively, with only 29% and 34%.

The sea-bob shrimp stock has not been assessed since D’Incao *et al.* (2002). However, it can be argued that redirecting effort for the Argentine red and stiletto shrimps in the recent years may be a response to declining biomass observed for the species in the 1990's decade. Even considering the very seasonal availability of the two southern shrimps (Baptista-Metri, 2007) and their strong inter-annual fluctuation in abundance due to environmental causes (Dumont *et al.*, 2011), the SBS fleet reveals to be highly dependent on these “new” resources. In addition, it is noteworthy that even presenting the pink-shrimp as the main target, the pink-shrimp icing fleet has also the southern shrimps as key resources contributing, together, with 27% of the revenues and 35% of the landings.

Making the Argentine red and stiletto shrimp official targets for all vessels pertaining to the sea-bob and pink-shrimp fleets cannot be considered a precautionary measure. Given that no catch or effort limits do exist for both species in Brazil, this measure threatens not only the biological sustainability of the respective stocks, but also the economic survivorship of the vessels that currently rely on these shrimps (Tables 8, 9). In addition, declining yields as resulting from a potential overexploitation or collapse of these stocks could intensify the compensatory strategy adopted by both fleets, augmenting their overlapping and, consequently, contributing for developing additional scenarios of effort concentration over other resources.

Regarding the demersal fish vessels, three main aspects deserve attention: a) in contrary to what would be expected, the most important category in their landings was neither the target nor the incidental species, but the “others” not listed in their respective licenses; b) codling, a species pertaining to the latter category, was the main item in landing and in revenue, and c) four of the most important species for this fleet (codling, Brazilian codling, flatfish and bluewing searobin) accounted for 20% of the pink-shrimp icing landings, indicating a significant catch similarity between them. While part of the dominance of the “other” category could be explained by eventual omissions in the list of species as defined by the fishing authority, actually, most of the discrepancies result from operations conducted below the 250 m isobaths as revealed by Benincá (2013). The high proportion that slope resources as codling, Argentine hake, and monkfish accounted for in the demersal fish fleet landings (Table 10) supports this view. Exploitation of these species started in Brazil in the 2000’s and were firstly developed by chartered foreign stern trawl and gillnet vessels which conducted exploratory fishing operations in the slope, and were soon replaced by domestic fleets (Perez *et al.*, 2009a, 2009b). Going deeper, out from the well-known shelf fishing grounds, this fleet confirms the opportunistic expansion of the regional industrial trawling fleets to new grounds, aiming at compensating the economic losses derived from the overexploitation of the traditional demersal resources (Perez & Pezzuto, 2006; Perez *et al.*, 2009b). Apart from increasing the range of species and areas to be exploited by the fleet, such behavior imply also in an uncontrolled fishing effort over the less abundant slope resources, whose limited biological productivity revealed to be incompatible with high mortality levels (Perez *et al.*, 2005; Perez, 2006; Haimovici *et al.*, 2006).

Interestingly, it is worth mentioning that, despite having the same licenses, the two pink-shrimp fleets behaved quite differently in almost all aspects, including, for instance, physical characteristics, mean number of days at sea and at fishing, main fishing areas, number of species landed and relative contribution in total landings and revenue. Such fact demonstrates that more than signifying only distinct strategies of catch conservation, using crushed ice of cold chambers in the pink-shrimp fishery can imply significant changes in the vessel dynamics too. While icing vessels’ landings were more diverse and abundant, freezer vessels showed a lower number of species and a revenue proportionally higher, which can be explained by the predominance of pink-shrimps in their landing composition. Not depending on the limited ice durability on a tropical sea, pink-shrimp freezer vessels are able to spend nearly twice more days at fishing then pink-shrimp icing ones, retaining their catch more selectively and favoring those items with higher economic value. Consequently, it is probable that those cold-chambered vessels produce much more discards during their fishing trips than the icing ones, aiming at keeping storage space for such preferential items. Studies specially designed to investigate discards in the two fleets are necessary to verify this hypothesis.

Our results point out the high diversity of items landed by all the fleets examined in the present study as the number of species/categories recorded varied from 50 (sea-bob shrimp) to 68 (pink-shrimp icing and demersal fishes fleets). As many commercial categories figured out in the landing statistics include more than a single biological species (*i.e.*, “mixture”; “sharks”), the real number of species effectively exploited by these fleets is certainly much higher. Studying the industrial double-rig landings in São Paulo State, Graça-Lopes *et al.* (2002b) recorded 70 biological species retained by sea-bob shrimp vessels between 1990 and 1991, and 137 by the pink-shrimp vessels which operated between 1989 and 1992. Kotas (1998) reported 103 biological species landed in Santa Catarina by industrial double-rig vessels directed to pink, Argentine red, Argentine stiletto and striped soldier shrimps during fishing trips conducted from 1993 to 1994. According to Haimovici & Mendonça (1996a), double-rig trawlers operating off Rio Grande do Sul between 1992 and 1993 retained 32 biological species or genera of fishes (no data were available for invertebrates), when directing their effort to the southern shrimps and flatfishes. In spite of been possibly influenced by different methods of study, sampling effort and commercial issues, declining number of retained species from São Paulo to Rio Grande do Sul could reflect, in part, a natural expected pattern of latitudinal reduction in species diversity towards the south.

Regardless the spatial, legal and operational differences observed, the regional industrial double-rig fleets clearly develop well-established multi-specific fisheries, using non-selective apparatus in a naturally biodiverse ecosystem. Thus, focusing the licensing system in extensive lists of species catchable over large areas, does not seem reasonable or even practical given the following reasons: a) currently, excepting the mandatory use of turtle excluder devices by the Brazilian shrimp fleets (Brasil, 2004), there is no locally available technology to avoid catching species not listed in the respective permissions, imposing serious limitations to the management of those species, and putting industry and fishers over constant legal risk; b) the adoption of a permissible fishing area, encompassing the entire southeast-south region, aggravates the situation, making it virtually impossible to eliminate spatial overlapping among fleets, and consequently, coincidence in their catch composition; c) expanding the already extended lists of species in the licenses by including more items would turn the system even more complex and questionable in both biological and operational basis; and d) even if such a procedure were adopted, enforcement would be unfeasible, since inspectors would require high taxonomic skills on an extremely diverse range of species.

As pointed out by Norse (2010), unlimited mobility as evidenced in the present study encourages sequential overfishing and reduces profitability, as declining fishing abundance near homeports compels fishermen go farther, invest in larger boats, deal with higher fuel, labor, and processing costs. Therefore, how the license system for demersal fisheries should be designed in Brazil? The solution is certainly not trivial considering the complexities involved in biological, economical, structural, legal, and operational terms. Possibly, besides reducing total effort and enhancing fishing control, the most reasonable option was pointed out by Perez *et al.* (2001) for the management of demersal and benthic resources exploited on shelf and slope grounds of the region. Instead of permitting the free operation of the fleets throughout this large area, the southeastern-south Brazil should be divided in smaller "geographical management units" (GMUs), *i.e.* spatially restrict and ecosytemically designed fishing grounds, to be defined mostly according to the spatio-temporal distribution of different stocks, bottom characteristics, depth, fleet dynamics and technical considerations. After knowing the potential for sustainable exploitation of the main (or the more vulnerable) resources inhabiting each GMU, safe levels of effort would be allocated to them, redistributing and limiting the respective number of boats authorized to operate within each unit. Vessels should be licensed fundamentally to operate: a) on a single or few management unit(s) and b) with a specific fishing method. Different from the current system where catch/landing composition is the main criteria on the licensing design, the species composition would be a natural consequence of the interaction between fishing technique and ecological characteristics of the fishing grounds. Enforcement would be feasible mostly through the national vessel monitoring program (PREPS) in order to guarantee that vessels remain operating within the GMU (s) for which they were authorized. Essentially, the system should move from a species-based to a spatial-based approach, which has been considered of high value whenever multiple uses of space and resources result in conflicts among users or among these and the environment (Pipitone, 2012). Such change in licensing approach corroborates Caddy & Seijo (2005) belief that spatial tools should gain a greater role in fishing management, even of polyvalent offshore fisheries, especially considering the low-cost represented by satellite monitoring systems in terms of monitoring, control and surveillance.

Designing of GMUs could benefit from a significant amount of studies regarding resource distribution, fishing dynamics and management of pot, long-line, trawl and gillnet fisheries for benthic/demersal species living either on the shelf as on the regional slope grounds (*e.g.,* Valentini *et al.*, 1991; Haimovici & Mendonça, 1996a, 1996b; Kotas, 1998; Perez & Pezzuto, 1998; Ávila-da-Silva *et al.*, 2001; Paiva *et al.*, 2001, 2002; Perez *et al.,* 2001, 2002a, 2002b, 2007, 2009a, 2009b; Graça-Lopes *et al.*, 2002a, 2002b; Perez & Pezzuto, 2006; Pezzuto *et al.*, 2006; Baptista-Metri, 2007; Ávila-da-Silva & Arantes, 2007; Castro *et al.*, 2007; Haimovici & Velasco, 2007; Silva, 2007; Tomás, 2007; Tomás & Cordeiro, 2007; Tomás *et al.*, 2007; Dumont & D'Incao, 2008; Alves *et al.*, 2009; Botelho *et al.*, 2009; Dallagnolo *et al.*, 2009; Pio, 2011; Valentini *et al.*, 2012; Benincá, 2013; Corrêa, 2013; Rolim, 2014). Otherwise, if adoption of such model is to be considered, determining current biomass of the several stocks, reference points, sustainable effort allocation levels, and technical measures to be implemented within the GMUs (including those designed to reduce discards) would be some of the main scientific and management challenges to be faced in the future, as most of this information is virtually inexistent, and/or strictly dependent on the proper GMU's characteristics to be determined.

Although the ideas of Perez *et al.* (2001) have been proposed for over a decade, even before the implementation of the current multi-species licensing system, results of the present study reinforce the need to consider and develop such idea as a concrete alternative, if biological sustainability, fisheries economic viability, management effectiveness and legal security of those involved in Brazilian multi-species and multi-fleet demersal fisheries are goals to be achieved.

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