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Bycatch of sharks (Elasmobranchii) in the Patagonian red shrimp *Pleoticus muelleri* (Bate, 1888) fishery

Paula V. CEDROLA[1], Alberto M. GONZÁLEZ[2], Gustavo E. CHIARAMONTE[3] & Alejandro D. PETTOVELLO[4]

[1]Consejo Agrario Provincial, 9050 Puerto Deseado, Argentina, paula_cedrola@yahoo.com.ar. [2]Subsecretaría de Pesca y Actividades Portuarias de Santa Cruz, Argentina. [3]División Ictiología, Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Ángel Gallardo 470 (1450) Buenos Aires, Argentina, gchiaram@mail.retina.ar. [4]Universidad Tecnológica Nacional, 9120 Puerto Madryn, Argentina, alejandro_pettovello@yahoo.com.ar

Abstract: The double–beam trawl fishery for the Patagonian red shrimp (*Pleoticus muelleri*) is the main crustacean fishery of the Southwestern Atlantic Ocean. The shark bycatch in 723 tows of this fishery was surveyed from April 2003 to October 2003. Six species of sharks were recorded: *Squalus acanthias* (n=321); *Squalus mitsukurii* (n=1); *Squatina* sp. (n=1); *Schroederichthys bivius* (n=327); *Galeorhinus galeus* (n=4) and *Mustelus schmitti* (n=13). Length-frequency structure, sex composition, spatial distribution and estimation of density and bycatch per unit of effort are given for the main species. The bycatch of sharks in this fishery was estimated in ~61 mt/year, equivalent to 0.15% of the shrimp total capture in 2003. *S. acanthias* contributed with 30.5 mt (50.15%) whilst *S. bivius* contributed with 22.6 mt (37.2%). Whereas the abundance for *S. acanthias* in Patagonian waters increased by three fold between 1997 and 2001, the abundance of *S. bivius* in the same period have decreased in the same amount. In addition, losses of important reproductive sites in southern Patagonia for *S. bivius* were detected. These issues together with the results presented herein add the Patagonian red shrimp fishery to the potential threats *S. bivius* is exposed to.

Key words: Southwestern Atlantic, elasmobranch, bycatch, fisheries.

Resumen: Captura incidental de tiburones (Elasmobranchii) en la pesquería del langostino patagónico *Pleoticus muelleri* (Bate, 1888). El langostino patagónico (*Pleoticus muelleri*) es la especie objetivo de la principal pesquería de crustáceos del Atlântico Sudoccidental. Durante 2003, se censaron todos los tiburones de 723 lances durante las operaciones normales de pesca. Se registraron seis especies de tiburones: *Squalus acanthias* (N=321), *Squalus mitsukurii* (N=1), *Squatina* sp. (N=1), *Schroederichthys bivius* (N=327), *Galeorhinus galeus* (N=4) y *Mustelus schmitti* (N=13). Para las dos especies mas frecuentes, se calcularon la distribución de frecuencia de tallas, la proporción de sexos, la distribución espacial, la densidad y la captura por unidad de esfuerzo. La captura de tiburones para 2003 se estimó en 61 tm (*Squalus acanthias* 30,5 tm y *S. bivius* 22,6 tm) equivalente al 0,15% de la captura total de langostino. Entre 1997 y 2001 la abundancia de *S. bivius* disminuyó, lo cual se suma a la pérdida de áreas de reproducción para la especie detectadas en la Patagonia sur. Este hecho, junto con los resultados presentados en este estudio, posicionaría a la pesquería del langostino patagónico como una potencial amenaza para *S. bivius*.

Palabras clave: Atlántico Sudoccidental, elasmobranquios, descarte, pesquerías.

INTRODUCTION

Bycatch is that portion of the capture discarded at sea dead or severely injured because it has little or no economic value or because its retention is prohibited by law (Hall, 1996). It is well known that bycatch is of great concern both ecologically and in terms of fisheries management, particularly in shrimp fisheries (Pettovello, 1999; Stobutzki *et al*., 2001; 2002; Carbonell *et al*., 2003). Sharks, skates and rays (Elasmobranchii) are frequently caught as bycatch, showing rapid declines in catch rates ('boom and bust' yields), with fisheries collapsing soon after initiation of heavy exploitation (Bonfil, 1994). Although there is some evidence that some elasmobranch species could be exploited sustainably at low fishing pressure, elasmobranchs taken as bycatch in fisheries targeting other species could be extirpated long before appropriate management policies

could be implemented (Walker & Hislop, 1998).

The Patagonian red shrimp *Pleoticus muelleri* (Bate, 1888) fishery is the main crustacean fishery in the Southwestern Atlantic Ocean and is targeted by the double-beam trawl fleet. Industrial fishing of *P. muelleri* began in Patagonia in 1979, with catches of the species reaching a maximum of 79,000 metric tones (mt) in 2001. Near 90 double-beam trawl vessels are involved in this fishery. Bycatch in the *P. muelleri* fishery is composed mainly of hake *Merluccius hubbsi* (Marini, 1933), although a total of 32 species have been recorded, including several unidentified elasmobranch species (Pettovello, 1999).

In the Argentine sea there are about 35 species of sharks; most of them are demersal with only few pelagic ones. The coastal demersal species, whose range includes the continental shelves of Argentina, Uruguay and Brazil, have been the most intensely exploited. Total declared landings of chondrichthyan fishes have increased in the last years. The smooth hound *Mustelus schmitti* (Springer, 1939) and skates are mainly accounting for this increase. These species, together with *Galeorhinus galeus* (Linné, 1758), *Squatina* spp. and *Carcharhinus brachyurus* (Günther, 1870) are the main commercial species in the Argentinean elasmobranch fisheries and have been caught mainly by the costal fleet (more than 50% of total declared shark landings, Chiaramonte, 1998). Fishery statistics obtained from reports published by the national fisheries authorities (Subsecretaría de Pesca y Agricultura de la Nación, SP/MEOSP) shows the evolution of declared landings from 1979 to 2009 for the main shark species under exploitation in Argentina (Fig. 1). Declared landings of elasmobranchs increased from 6,614 mt in 1979 to 44,036 mt in 2007, almost 700%. This means that Argentine sharks' catches represent 4,26% of the total reported shark catch to the United Nations Food and Agriculture Organization FAO (Lack & Sant, 2011).

Worldwide, there is increasing concern over the capture of elasmobranchs. In 2008, the global landing of elasmobranchs was 736,491 MT (FAO 2010). But Dulvy *et al.* (2008) state that sharks catches may be 3–4 times as large as those recorded by FAO, after having analysed the number and biomass of sharks entering sharks fin trade each year. Bycatch of elasmobranchs is often not recorded (Bonfil, 1994) and when it is, the species composition remains unknown. This is due to the traditionally low value of most shark species relative to the target species they are typically caught. These factors have translated into these species having low priority for fisheries management (Dulvy *et al.*, 2008). This lack of species-specific data posses a significant challenge to quantifying the impacts of exploitation on these species and may mask declines and local extinctions (Dulvy *et al.*, 2000).

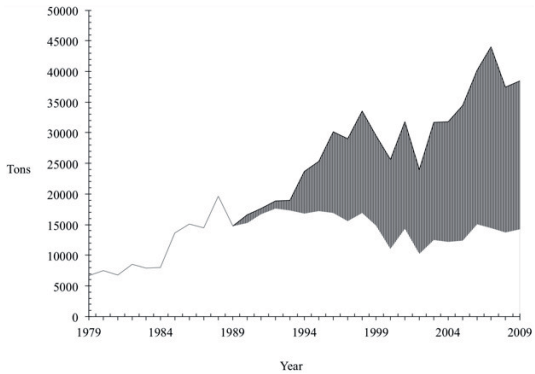

Fig. 1. Shark landings in Argentina (1979–2009).

In Argentina, bycatch of elasmobranchs were recorded by Van der Molen *et al.* (1998), who recorded species sharks composition of the bycatch in the Patagonian coastal trawl fisheries, by Cedrola *et al.* (2005), who estimated the bycatch of skates in the Patagonian red shrimp fishery in 1,000 mt and by Tamini *et al.* (2006) who analyzes the batoids composition of the bycatch in a coastal fishery at Buenos Aires province.

The aim of this work is to identify sharks species in the bycatch of the Patagonian red shrimp fishery and to estimate whenever possible by species, their length-frequency structure, sex composition, spatial distribution, bycatch per unit of effort (BPUE) and density for the main species, dogfish *Squalus acanthias* (Linné, 1758) (and narrowmouth catshark *Schroederichtys bivius* (Müller & Henle, 1841).

MATERIALS AND METHODS

Onboard sampling was carried out in the double-beam trawler vessels operating in the Patagonian shelf (44° S to 47° 30´ S and 63° W to 68° W, Fig. 2) during a whole fishing season, from April 2003 (beginning of the season) to October 2003 (end of the season), during normal fishing operations. General methodology follows Cedrola *et al.* (2005): all sharks were separated from a single randomly selected tow each fishing day. Each specimen was identified to species level, measured, weighed and sexed. Total length (TL) was recorded to the nearest millimetre, from the

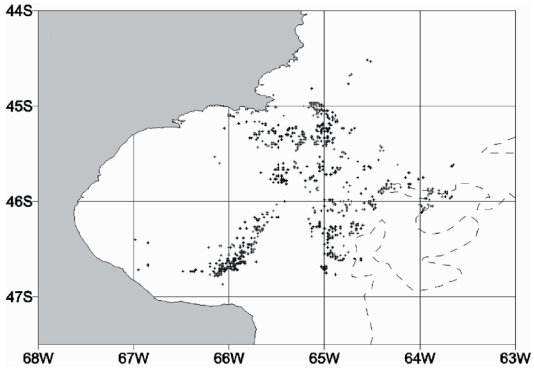

Fig. 2. Sampled tows (n=723) of the Patagonian red shrimp fishery from April 2003 to October 2003. Dotted line: isobath of 100 meters.

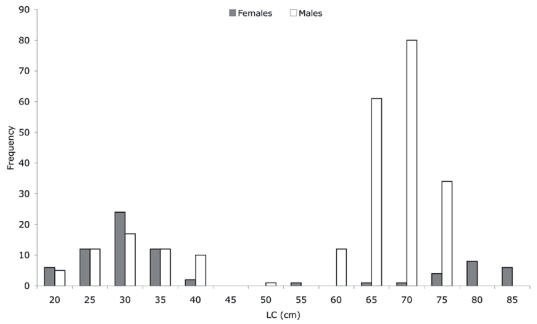

Fig. 3. Length-frequency of *Squalus acanthias* by sex in the bycatch of the Patagonian red shrimp fishery, from April 2003 to October 2003.

tip of the snout to the tip of the upper lobe of the caudal peduncle at natural position, and mass (M) was registered to the nearest gram. Data of each tow were registered (date, initial latitude and longitude, depth, tow speed, and catch of shrimp and other species). Shrimp catches of the whole fleet during the period under study were obtained from logbook data. In order to calculate density of each species, swept area by tow (A) was calculated as $A=tva$, where t is the tow duration, v the speed, and a the horizontal opening of the net. Monthly bycatch per unit of effort (BPUE, in kg h^{-1}) and sex ratios (tested by χ^2 test) were calculated only for the main species (dogfish and catshark) present in the bycatch.

RESULTS

A total of 723 hauls were surveyed with a total effort of 1,029 h 27 min (Fig. 2.) Depth range surveyed was 65–117 m (mean depth 88.9 m). Average tow duration was 85 min (ranging 10–220 min). Average tow speed was 6.4 km h^{-1}. Catch composition during the survey was 312,001 kg of shrimp, 206,750 kg of hake, and 79,410 kg of other species, including 477 kg of sharks.

Six species of sharks were obtained during the survey: dogfishes *Squalus acanthias* and *S. mitsukurii* (Jordan & Snyder, 1903), (Squalidae), angelshark *Squatina* sp. (Squatinidae), narrowmouth catshark *Schroederichthys bivius* (Scyliorhinidae), school shark *Galeorhinus galeus*, and smoothhound *Mustelus schmitti* (Triakidae).

Dogfish *Squalus acanthias* (n=321) was present in 58 tows (8.04% of the sampled tows). Total caught was 237.2 kg, in depth range 68–116 m with an average range of 91 meters. Two modes were detected for both sexes (Fig. 3): one mode ranged 200–400 mm TL while the other 600–800 mm TL. Overall female: male sex ratio was 0.315:1.000, which is significantly different from 1:1 ($\chi^2=86.88$, $P<0.05$). The species was present in seven rectangles (1° latitude x 1° longitude), and males dominated in five of them. Females were more abundant in the two remaining rectangles (44° S - 65° W and 46° S - 66° W; Fig. 4), but there were not significant differences from female:male 1:1 sex ratio ($P>0.05$). Dogfish was present during the whole fishing season. Mean monthly BPUE was 0.258 kg h^{-1} (Table 1), reaching 0.3 kg h^{-1} in October, with a maximum of 0.44 kg h^{-1} in August. Maximum density reached up to 0.68 mt km^{-2} in the northeastern limit of the San Jorge Gulf (45° S - 65° W) (Fig. 4).

A single individual of *Squalus mitsukurii* (n=1; 0.14%), a male of 1.2 kg, was caught at 45° S - 65° W (depth 87 m). Angelshark *Squatina* sp. (n=1) was also present in 1 tow (0.14%). The specimen was a female of 6.3 kg caught at 76 m of depth at 45° S - 64° W.

Narrowmouth catshark *Schroederichthys bivius* (n=327) was present in 77 tows (10.68%). Total catch was 175.22 kg, ranging 68–116 m depth (average depth 89 m). The narrowmouth catshark shows an unusual secondary sexual dimorphism, with longer males than females (Fig. 5), with the bulk of the female specimens range between 400 mm and 600 mm of TL, whilst males had the maximum sizes between 600 mm and 800 mm of TL. This species was abundant in the southern area under study; exhibit a wider range of sizes (Fig. 5). Overall female:male ratio was 0.537:1.000, which results significantly different from 1:1 ($\chi^2=29.37$, $P<0.05$). This species was present in eight rectangles (Fig. 6). Males was dominant in seven of these rectangles, whilst fe-

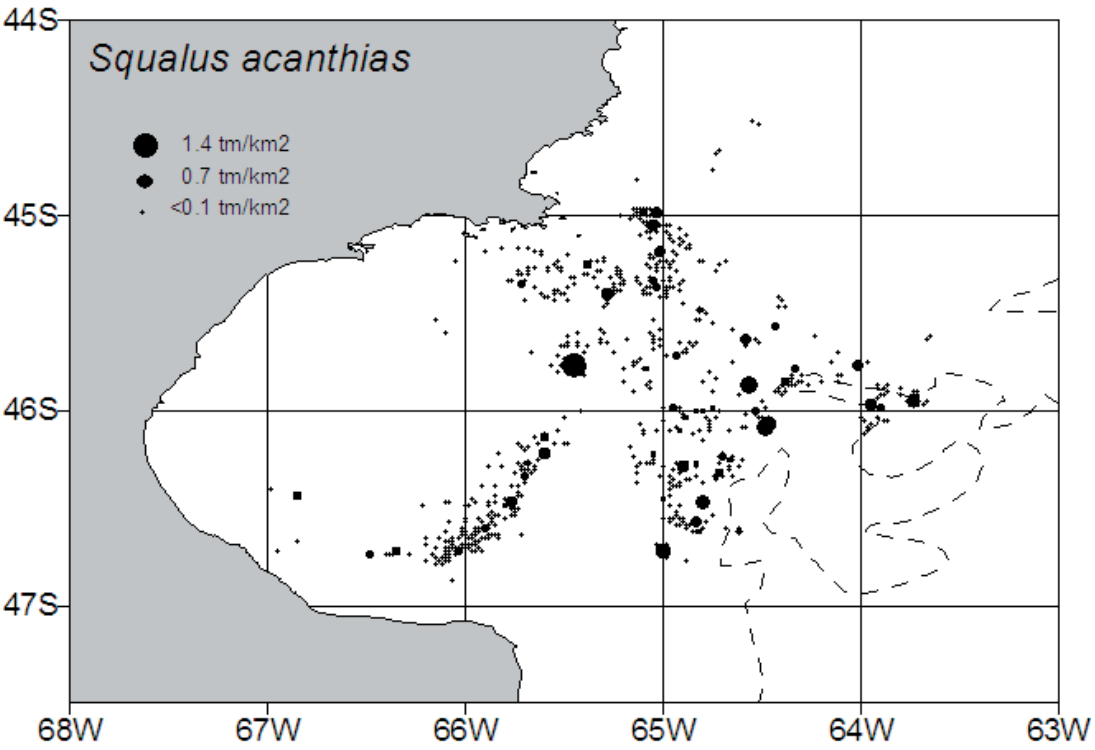

Fig. 4. Density (tm km^{-2}) of *Squalus acanthias* in the bycatch of the Patagonian red shrimp fishery, from April 2003 to October 2003.

males was dominant only around 46° S - 66° W, but these dominances were not significant different from 1:1 sex ratio ($P<0.05$). *S. bivius* was present from April to October, except in August. Mean monthly BPUE was 0.144 kg h^{-1} (Table 1), increased from 0.13 kg h^{-1} in April to its maximum of 0.24 kg h^{-1} in July. Maximum density reached up to 1.57 mt km^{-2} out of San Jorge Gulf (Fig. 6).

School shark *Galeorhinus galeus* (n=4) was present in 4 tows (0.55%). Total catch was 44.8 kg, depth range 76–83 m, and the average depth was 75.8 meters. All individuals were males.

Mustelus schmitti (n=13) was present in 11 tows (1.52%). Total catch was 13.7 kg, depth range was 76–109 m and the average range was 87 meters. Overall female: male ratio was 2.25:1.00, although this difference was not statistically significant ($\chi^2=1.92$, $P>0.05$).

We estimate that during the 2003 fishing season, shark bycatch was 61 mt, near 0.15%of shrimp total catch (41,000 mt). Estimation of bycatch of *Squalus acanthias* was 30.5 mt (50.15% of shark bycatch biomass), and *S. bivius* was 22.6 mt (37.2%of shark bycatch biomass).

DISCUSSION

Of the nine shark species inhabiting the area under study (Arquez *et al*., 1986; Caille & Olsen 2000; van der Molen & Caille, 2001), six were found as bycatch of the Patagonian red shrimp fishery. The dogfish *Squalus acanthias* and the narrowmouth catshark *Schroederichthys bivius* were by far the most abundant species of sharks captured by the double-beam shrimp fleet. At least half of the shark bycatch biomass was *Squalus acanthias*, one of the most abundant shark species in Argentinean waters. Cousseau & Perrota (2004) quoted 34° S as its northern range distribution. Garcia de la Rosa (2000) found this species in waters ranging 4° to 19° C, from 34° S to 55° S, and depths from 17 to 520 meters. Gosztonyi & Kuba (1998) mentioned *S. acanthias* inhabiting the Argentinean continental shelf from Buenos Aires Province (34° S) to the Beagle Channel in depths up to 340 meters. Compagno (1984) quoted 950 m of depth as an exceptional limit for the species. We found an average depth of 91 m, because our study was carried out in coastal fishery grounds.

Size range of *S. acanthias* found in our study

Table 1. Bycatch per Unit Effort (BPUE) in kg h^{-1} for *Squalus acanthias* and *Schroederichthys bivius* in the Patagonian red shrimp fishery (this work) and in the Argentinean hake fishery (based in Cañete *et al*. 1999). In this last fishery, two level of fleet were discriminated.

	This work				Cañete *et al.* (1999)			
	Fleet	BPUE (kg h^{-1})	±S.E.	Range	Fleet	BPUE (kg h^{-1})	±S.E.	Range
Squalus acanthias (*Squalus* spp.)	Double-beam trawler	0.258	0.50	0.00–0.44	Freezer trawler	15.67	5.84	0.01–86.18
	–	–	–	–	Ice trawler	8.85	4.69	0.37–88.75
Schroederichthys bivius	Double-beam trawler	0.144	0.04	0.00–0.24	Freezer trawler	0.45	0,11	0.05–1.00
	–	–	–	–	Ice trawler	0.04	0,24	0.01–1.63

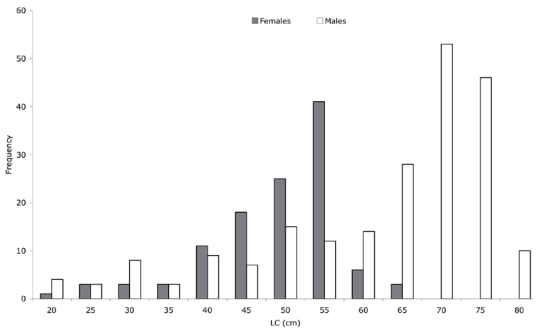

Fig. 5. Length-frequency of *Schroederichtys bivius* by sex in the bycatch of the Patagonian red shrimp fishery, from April 2003 to October 2003.

did not show differences from previous studies (Menni, 1985; Gosztonyi & Kuba, 1998; Garcia de la Rosa, 1998), although mean sizes found in our work seem to be far from those values for both sexes. Menni (1985) reported lengths of maturity for females larger than 700 mm of TL and near of 630 mm of TL for males. According to maturity sizes given by Menni (1985) and Gosztonyi & Kuba (1998), seventy three percent of sampled females of *S. acanthias* were juveniles (size range 200–380 mm TL), and could affect the offset mechanism of birth in the population as Walker (1994) showed for other shark species. Most of the males of the species found in our study (76%) were adults (size range 590–750 mm TL). Taking into account the significant differences in sex ratios found in this work, the population of *S. acanthias* caughed as bycatch of the Patagonian red shrimp showed a social and size segregation, a fact previously reported by Springer (1967), Menni (1985), and Garcia de la Rosa (1998) for Argentinean dogfish populations.

Narrowmouth catshark *S. bivius* is an endemic, widely distributed species in the Patagonian Shelf and costal waters, from Buenos Aires province to Tierra del Fuego (Gosztonyi, 1981). The species shows, as reported by Menni *et al*. (1979) and Menni (1986), an unusual secondary sexual dimorphism, with longer males than females. The size range observed in our study (♀: 200–640 mm; mean: 472 mm; ♂: 190–800 mm; mean: 605 mm) is wider than those reported by Menni *et al*. (1979) for the species. We also found smaller specimens and the average sizes are lower than those quoted by the former authors. Menni *et al*. (1979) reported maturity lengths for females larger than 512 mm of TL and for males between 655 and 660 mm of TL. Our results showed mean sizes smaller than those for maturity observed by these authors. Nevertheless, most of the specimens of *S. bivius* censed were adults (59% of females and 72% of males). Taking into account the significant differences in sex ratios found in this work, the population of *S. bivius* captured as bycatch of the Patagonian red shrimp showed a social and size segregation as mentioned above for *S. acanthias*. Menni *et al*. (1979) regarded this segregation with depth, but we couldn't be able test those findings. In the San Jorge Gulf, BPUE of this species was higher during winter. Skates fished as bycatch in the same fishery also had maximum BPUE in this season (Cedrola *et al*., 2005).

The life history strategy (characterized by slow growth, late attain of sexual maturity, long life spans and low natural mortality) is a common feature of several elasmobranchs species, and made them particularly vulnerable to overexploitation (Hoening & Gruber 1990; Stevens *et al*., 2000). In this perspective, the Patagonian red

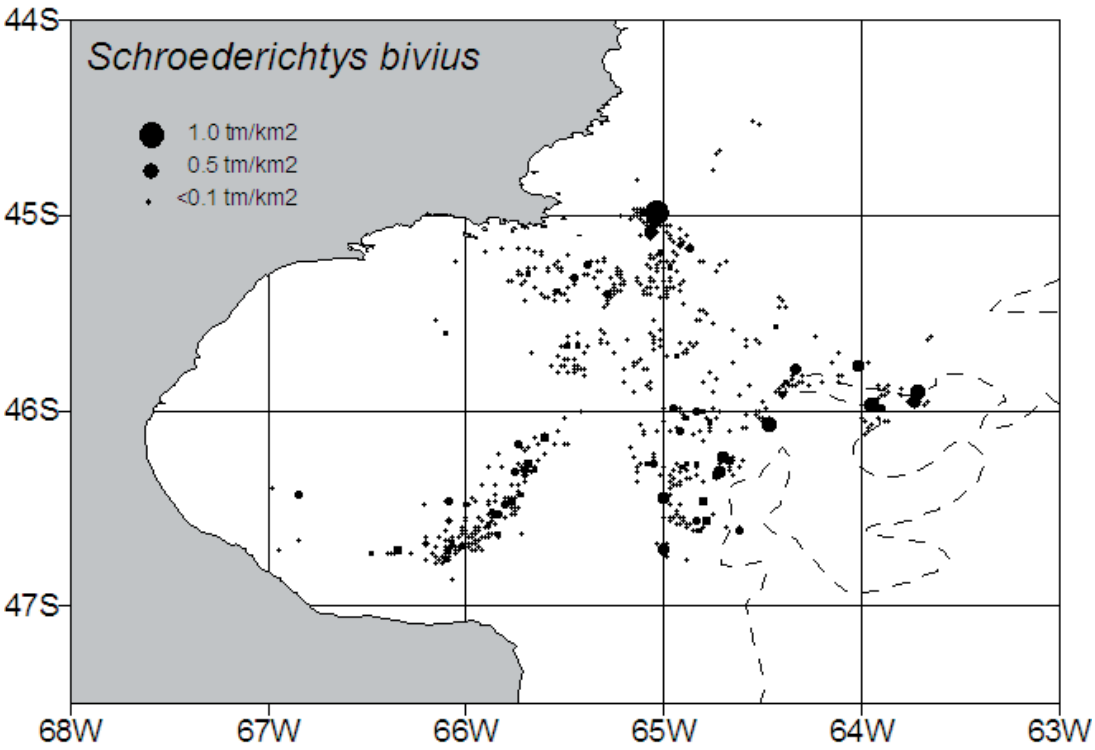

Fig. 6. Density (tm km^{-2}) of *Schroederichthys bivius* in the bycatch of the Patagonian red shrimp fishery, from April 2003 to October 2003.

shrimp fishery could be impact on the shark species populations in different ways with species-specific responses to this pressure. For the viviparous shark *S. acanthias*, the average annual bycatch in the Patagonian red shrimp fishery corresponds to the 0.04% of the total average biomass reported by the INIDEP surveys between 1992 and 2001 (Marí, 2005). In the same way, the average annual bycatch in the Patagonian red shrimp fishery of the oviparous shark *S. bivius* represents the 0.07% of the total biomass reported by the INIDEP surveys between 1992 and 2001 (Marí, 2005). Comparing the BPUE figures obtained in this work with the our analyses of the results in Cañete *et al*. (1999) for the hake fishery (Table 1) the incidence of the Patagonian red shrimp fishery is relatively low for *S. acanthias* and in the same degree of magnitude that of the hake fishery for *S. bivius*. However, the conservation status of the two most abundant shark species in the bycatch of the Patagonian red shrimp fishery might not be the same. Whereas the abundance assessed by the INIDEP for *S. acanthias* –a cosmopolitan shark species– increased by three fold between 1997 and 2001, the assessed abundance of the endemic shark *S. bivius* in the same period have decreased in the same amount, and may be cause for concern. In addition, there is also a detected loss of important reproductive sites in southern Patagonia for *S. bivius* (Chiaramonte, 2005). In conclusion, these issues together with the results presented herein add the Patagonian red shrimp fishery to the potential threats *S. bivius* is exposed to.

CONCLUSIONS

The Patagonian red shrimp fishery impacts 6 of the 9 shark species inhabiting the area under study.

The cosmopolitan dogfish *S. acanthias* and the endemic narrowmouth catshark *S. bivius* were the most abundant species of sharks in the fishery.

The 73% of sampled females of *S. acanthias* were juveniles, whereas the 76% of males were adults.

The 59% of females and 72% of males of *S. bivius* censed were adults.

Bycatch of *S. acanthias* in the Patagonian red shrimp fishery is relatively low.

The Patagonian red shrimp fishery produces a

similar level of bycatch of *S. bivius* that the produced in the hake fishery.

The Patagonian red shrimp fishery appears as a potential threat for *S. bivius*.

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