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Note

Skates in the demersal trawl fishery of San Matías Gulf, Patagonia: species composition, relative abundance and maturity stages

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Abstract – Argentina is one of the countries with the largest overall landings of skates and rays (24 000 t/year). As a consequence of high levels of exploitation and deficient management tools, many of these species are threatened with extinction. In the bottom trawl fishery of San Matías Gulf, northern Patagonia, skates and rays are caught as bycatch and all have historically been recorded in the fishery logbook under the category "rays". Therefore, species composition and their characteristics were unknown. The aim of this study was to characterize the commercial exploitation of batoid species in this fishery. Our results indicate that commercial landings include nine species of skate, six of which are common. Among these, *Atlantoraja platana*, *Sympterygia bonapartii* and *Dipturus chilensis* were considered the main species of this fishery. Their combined relative abundance and weight made up about 90% of the batoid catch throughout the year. Sexual segregation was detected in four species in which individuals of one sex dominated commercial landings. The commercial fraction was composed of individuals with a wide range of sizes. Immature individuals could represent 90% of the individuals landed for some species. At present, lack of data prevents us from quantifying the impact that this fishery is having on these species, but our findings highlight the importance of conducting research surveys to assess the abundance and geographic extent of these populations. The information presented here provided the basis for the proposal of a new logbook format incorporating species-level identification. The new logbook was implemented on 1 January 2010.

Key words: Chondrichthyes / Elasmobranch / Rajidae / Commercial landings / Argentina / Southwest Atlantic

1 Introduction

Annual batoid (skates and rays) landings worldwide have been around 250 000 t over the last few years (FAO 2010). These species are caught mainly as bycatch in fisheries targeting more valuable species, although in some countries they are also fished as target species themselves (Bonfil 1994; Stevens et al. 2000; Field et al. 2009). As chondrichthyans, they have a life history strategy characterized by slow growth, late maturing age, low fecundity, low productivity, low natural mortality and a long lifespan. These features make them vulnerable to high levels of exploitation (Hoenig and Gruber 1990; Stevens et al. 2000; Field et al. 2009). Declines in their abundances and changes in their community structures have been reported by several authors (Brander 1981; Casey and Myers 1998; Walker and Hislop 1998; Agnew et al. 2000; Dulvy et al. 2000; Figueiredo et al. 2007).

Argentina is one of the countries with the largest overall landings of these species worldwide (FAO 2010). As a consequence of high levels of exploitation and deficient management tools, the coastal waters of Argentina, Uruguay and southern Brazil are among the regions with the largest amount of threatened chondrichthyan species (Field et al. 2009), many of then batoids (Batoidea: sawfishes, guitarfishes, electric rays, skates, and sting rays). About 45 species of skates and rays, 16 of which are of commercial interest, have been recorded on the Argentinean continental shelf (Cousseau et al. 2007). Landings increased steadily from 900 t in 1993 to 28 000 t in 2007, reaching an average of 24 000 t in the last two years (Ministerio de Agricultura Ganadería y Pesca 2010). Skates and rays are caught mainly as bycatch by industrial bottom trawlers, although since 1999 they have also been targeted by a long-liner with a maximum allowable catch of 1800 t per year.

San Matías Gulf (SMG) is situated in northern Patagonian waters (41–42°S; 64–65°W), where a bottom trawl fishery has been established since 1971 (Di Giácomo and Perier 1992).

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Its annual landings are around 13 000 t, constituting an economically important activity for the region. In this fishery, the common hake, *Merluccius hubbsi*, is the target species, and chondrichthyans are captured as bycatch (Di Giácomo and Perier 1991). During 2009, the chondrichthyan with the highest total landings was the holocephalan *Callorhynchus callorhynchus* (1457 t), followed by batoids (448 t) and sharks (240 t). About 19 batoid species have been recorded in these waters (Perier et al. 2007). Commercial batoids have historically been recorded in the logbook under the category "rays", without details on species composition or other characteristics. The aim of this study was to identify batoid species, and to analyze their relative abundance, length frequency structure and the proportion of immature individuals and sexes that composed commercial landings in the demersal trawl fishery of San Matías Gulf.

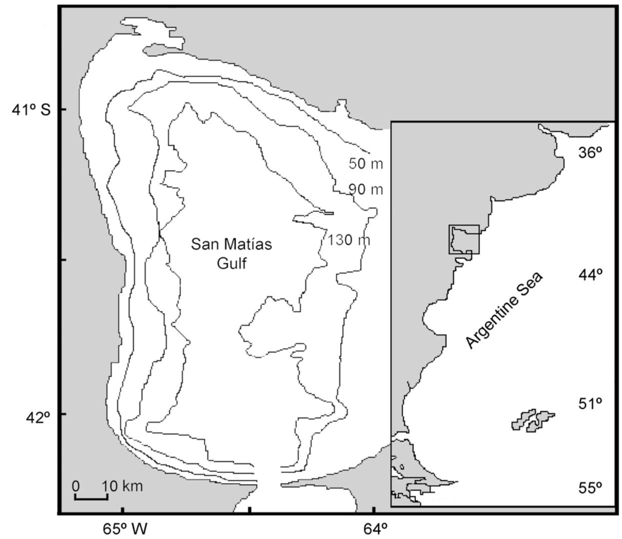

Fig. 1. Geographical localization of the study area.

2 Materials and methods

Commercial landings of batoids were sampled once or twice a month at local fish-processing plants from April 2007 to February 2009 (except in the months of December 2007 and November 2008) and during June, August, November and December 2009. Every month, a minimum of 10 boxes from a single trawler were randomly selected and sampled. During the 2007–2009 period, the demersal trawl fishery of San Matías Gulf was composed of 14–16 vessels. In this study, 11 of these vessels operating from San Antonio Oeste port were sampled. Bottom trawlers were from 16 to 29 m long. They fished in the gulf (Fig. 1) between the isobaths of 90 and 130 m, following the main concentrations of the common hake, the target species of the fishery (Di Giácomo and Perier 1991). In San Matías Gulf, the temperature of the surface water is from 11 to 18 °C, while the temperature of the bottom from 10.4 to 11.3 °C (Perier and Di Giácomo 2002).

Batoid species were classified following Cousseau et al. (2007) and families were assigned according to McEachran and Aschliman (2004). Species were classified as *common* when they were recorded in more than 50% of the samples, *frequent* when they were recorded in 20 to 49%, *occasional* when they were found in 5 to 19% and *rare* when they were recorded in less than 5% of the samples.

The number and sex of individuals of each species were recorded. Whenever possible, total length (TL) to the nearest cm, total weight (W) in grams and maturity stages were determined for each individual. Males were classified as immature when claspers either did not attain the margin of the pectoral fins or when they exceeded the pectoral fins but were flexible, and as mature when claspers exceeded the pectoral fins and were completely calcified. Females were classified as immature when oviducts, oviducal gland and ovaries were undeveloped or developing with no yolked oocytes in the ovaries, and as mature when oviducal glands and oviducts were completely developed and ovaries presented yolked oocytes (modified from Stehmann 2002).

The smallest mature individual was recorded and when possible, size at 50% of maturity (TL_{50}) was estimated using the FISHPARM 3.05 program (Prager et al. 1987). Length and weight relationships were estimated for each sex and compared using a *t*-test (Zar 1984). Curves were considered significantly different when $p < 0.05$. Additional information obtained from research cruises between 2004 and 2007 and the observer program were used to estimate these curves. When available, length and weight relationships and TL_{50} were used to infer the weight and maturity stage of individuals. The relative abundance of each species was analyzed, as well as their seasonal variations and relative contribution in terms of weight. The proportion of immature individuals and sexes and their seasonal variations were assessed using a χ^2 test (Zar 1984). Differences were considered significant when $p < 0.05$.

3 Results

3.1 Species contribution

A total of 31 visits to the local fish-processing plants were made from April 2007 to December 2009, over which a total of 7057 batoids were sampled. Nine species of skates (Rajidae) were recorded in commercial landings. *Dipturus* (=*Zearaja*) *chilensis* was recorded in all samples. This species together with *Atlantoraja platana*, *Sympterygia bonapartii*, *Dipturus trachyderma*, *Atlantoraja castelnaui*, and *Atlantoraja cyclophora*, were considered *common* species; *Rioraja agassizii* was *frequent*; while *Bathyraja brachyurops* and *Bathyraja macloviana* were *rare* (Table 1).

The most abundant species were *S. bonapartii*, *A. platana* and *D. chilensis*. These were the dominant species throughout the year, collectively contributing more than 90% of the individuals sampled. *A. platana* was the most abundant species in autumn and summer, while *S. bonapartii* was the most abundant in spring and winter (Fig. 2). The relative abundance of the other six species was considerably lower (Table 1; Fig. 2).

The relative weights of the species were estimated using the length and weight relationships (Table 2). *A. platana* was

Table 1. Species composition and contributions to commercial landings. Latin and common names; status in the IUCN Red List of Threatened Species; percentage of occurrence, relative abundance and weight. Bold type indicates the contributions of the dominant species.

Species		Common name (English/Spanish)	IUCN status*	Occurrence (%)	Relative abundance (%)	Relative weight (%)
Atlantoraja castelnaui	(Miranda Ribeiro 1907)	Spotback skate/Raya a lunares	EN	71	3.2	4.5
Atlantoraja cyclophora	(Regan 1903)	Eyespot skate/Raya de ocelos	VU	68	3.2	1.8
Atlantoraja platana	(Günther 1880)	La Plata skate/Raya platana	VU	**97**	**34.5**	**41.8**
Rioraja agassizii	(Müller and Henle 1841)	Rio skate/Raya lisa	VU	22	0.2	0.1
Sympterygia bonapartii	Müller and Henle 1841	Smallnose fanskate/Raya marmorada	DD	**97**	**35.1**	**26.5**
Dipturus chilensis	(Guichenot 1848)	Yellownose skate/Raya picuda	VU	**100**	**21.5**	**21.3**
Dipturus trachyderma	(Krefft and Stehmann 1975)	Roughskin skate/Raya de vientre áspero	VU	74	1.5	4
Bathyraja brachyurops	(Flower 1910)	Broadnose skate/Raya de cola corta	LC	3	0.7	
Bathyraja macloviana	(Norman 1937)	Patagonian skate/Raya espinosa	NT	3	0.01	

* IUCN: International Union for Conservation of Nature, Red List of Threatened Species – see definitions on their website; Least concern (LC), near threatened (NT), vulnerable (VU), endangered (EN), critically endangered (CR). IUCN URL: http://www.iucnredlist.org/

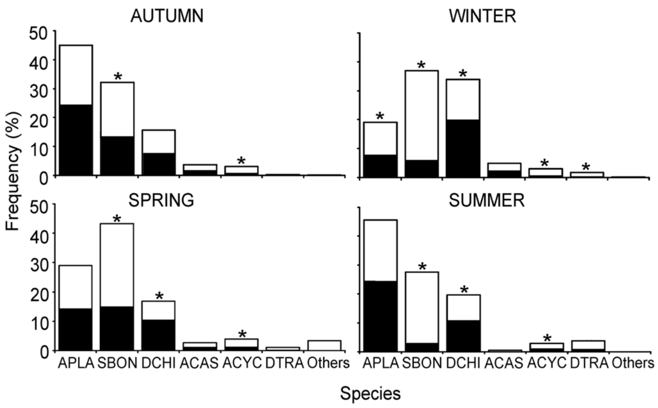

Fig. 2. Seasonal variation in relative abundance by sex of the species in commercial landings. (*): Significant differences in proportions of males (black bar) and females (white bar). APLA: *Atlantoraja platana*; SBON: *Sympterygia bonapartii*; DCHI: *Dipturus chilensis*; ACAS: *Atlantoraja castelnaui*; ACYC: *Atlantoraja cyclophora*; DTRA: *Dipturus trachyderma*; Others: *Rioraja agassizii*; *Bathyraja macloviana* and *Bathyraja brachyurops*.

the main contributing species, representing almost 42% of the total weight of the sample (Table 1). This species together with *S. bonapartii* and *D. chilensis* represented almost 90% of the total weight. The other species each accounted for less than 5% of the estimated catch weight. *Bathyraja macloviana* and *B. brachyurops* were excluded from this analysis because their weights could not be recorded and no length and weight relationships had been previously reported.

3.2 Length frequency structures, proportion of immature individuals and sexes

3.2.1 Atlantoraja platana

Sexes were equally represented in the samples as a whole, but females were more abundant during winter (Table 2; Fig. 2). More than 80% of the individuals caught were smaller than 70 cm (Fig. 3). Immature individuals accounted for 63% of the males and 77% of the females sampled and dominated in all seasons. The lowest percentage of immature individuals was recorded in winter, while the highest was recorded in autumn (Fig. 4). Females bearing egg capsules accounted for 62% of the mature females assessed ($n = 81$). They ranged from 68 to 88 cm and were found throughout the year, except in April and September.

3.2.2 Sympterygia bonapartii

Females dominated in the samples from all seasons (Table 2; Fig. 2). More than 80% of the individuals caught were smaller than 60 cm (Fig. 3). Immature individuals accounted for 61% of the males and 48% of the females sampled. The proportion of immature individuals was only higher than that of mature ones in spring. In winter and summer, mature individuals were more abundant and no significant differences were recorded in autumn (Fig. 4). Females bearing egg capsules accounted for 8.9% ($n = 16$) of the mature females sampled. They ranged from 60 to 73 cm in total length and were found from November to February.

Table 2. Commercial batoid species. Number of individuals sampled (N); male: female ratio, with significant differences in χ^2-test indicated by *; length at fifty percent of maturity (TL_{50}); total length (TL) and weight (W) relationships, given with the number of individuals used to for this estimate (n) and the correlation coefficient (R^2). Other data references: (a) Colonello (2009), (b) Coller unpublished data; (c) Estalles et al. (2009); (d) Cedrola et al. (2005); ** denotes estimated weight range of the individuals sampled.

Species	Sex	N	Sex ratio M:F	Size range (cm)	Smallest mature (cm)	TL_{50} (cm)	n	R^2	W(g)-TL(cm) relationships $W = f(\text{TL})$	n	R^2
Atlantoraja castelnaui	F	112	1:1	48–125	107	109[a]			$0.0037 \times TL^{3.1136}$		
	M	113		46–112	93	98[a]					
Atlantoraja cyclophora	F	151	1:2*	34–69	54	59	299	0.97	$0.008 \times TL^{2.983}$	227	0.99
	M	78		36–62	49	53	183	0.98	$0.012 \times TL^{2.8531}$	139	0.98
Atlantoraja platana	F	1243	1:1	33–88	66	72[b]			$0.017 \times TL^{2.849}$ [b]		
	M	1196		29–83	54	64[b]					
Rioraja agassizii	F	8	–	46–59	59	57[c]			460–590**[c]		
	M	4		41–52	55	50.4[c]			410–520**[c]		
Sympterygia bonapartii	F	1769	1:2.5*	34–75	52	59	1168	0.99	$0.0039 \times TL^{3.155}$	895	0.99
	M	711		32–69	46	56	489	0.99	$0.007 \times TL^{2.9957}$	409	0.99
Dipturus chilensis	F	650	1:0.8*	37–119	75	93.5	258	0.99	$0.0051 \times TL^{3.0435}$	691	0.98
	M	867		39–100	74	83	294	0.99	$0.0034 \times TL^{3.1561}$	1216	0.99
Dipturus trachyderma	F	93	1:7*	48–125	90				$0.0024 \times TL^{3.1715}$ [d]		
	M	14		46–90	83				$0.0024 \times TL^{3.1755}$ [d]		
Bathyraja brachyurops	F	66	1:2*	51–77	66						
	M	16		55–72	68						
Bathyraja macloviana	F	1		60	–						

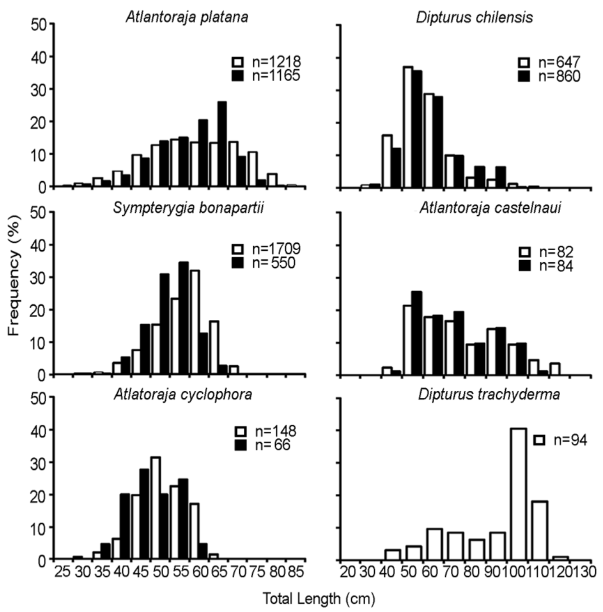

Fig. 3. Size frequency distribution of the common species. Males (black bars) and females (white bars). For *Dipturus trachyderma*, sexes were combined.

3.2.3 Dipturus chilensis

Males dominated in the samples as a whole, except in autumn, when sexes were equally represented (Table 2; Fig. 2). More than 80% of the individuals caught were smaller than 60 cm (Fig. 3). Immature individuals accounted for 88% of the males and 96% of the females sampled and dominated in all seasons, ranging from 83% in summer to 96% in autumn (Fig. 4). Females bearing egg capsules accounted for 43% of the mature females sampled (n = 28). They ranged from 95 to 110 cm in total length and were found from January to March and from June to September.

3.2.4 Atlantoraja castelnaui

Both sexes were equally represented in the samples as a whole and seasonally (Table 2; Fig. 2). Summer was excluded from the analysis because only seven individuals were recorded in that season. More than 80% of the individuals caught were smaller than 80 cm (Fig. 3). Immature individuals accounted for 88% of the males and 90% of the females sampled and they dominated in all the seasons evaluated, ranging from 76% in autumn to 92% in winter. Summer was excluded from the analysis since not enough individuals were recorded in this season (Fig. 4). Four females bearing egg capsules and measuring between 107 and 125 cm were found in July, August and October.

3.2.5 Atlantoraja cyclophora

Females dominated in the samples as a whole, except in summer, when sexes were equally represented (Table 2;

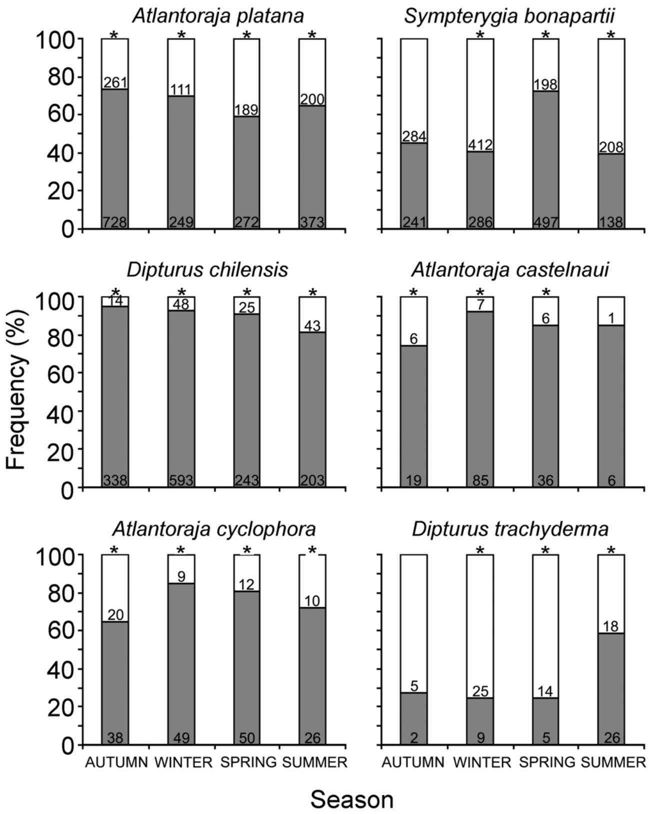

Fig. 4. Seasonal variation in the proportion of mature (white bar section) and immature (grey bar section) individuals of the common species. (*): Significant differences in the χ^2-test. The number of individuals sampled is indicated inside the bars.

Fig. 2). More than 80% of the individuals caught were smaller than 50 cm (Fig. 3). Immature individuals accounted for 73% of the males and 78% of the females sampled and they dominated in all seasons, ranging from 66% in autumn to 84% in winter (Fig. 4). A female of 62 cm was found bearing egg capsules during December.

3.2.6 Dipturus trachyderma

Females dominated in the samples as a whole, during all seasons (Table 2; Fig. 2). Autumn was excluded from the analysis because not enough individuals were recorded in that season. Most of the specimens sampled (60%) were larger than 100 cm (Fig. 3). Immature individuals accounted for 86% of the males and 33% of the females sampled. The proportion of mature individuals was higher than that of immature ones in winter and spring (Fig. 4). Females bearing egg capsules accounted for 42% of the mature females sampled (n = 60). They ranged from 90 to 125 cm and were found in January, March, June to October and December.

Bathyraja brachyurops and *B. macloviana* were found on only one occasion, in November 2009. For *B. brachyurops*, immature individuals accounted for 80% of the males and 61% of the females sampled. For *Rioraja agassizi*, 60% of the individuals sampled were immature.

4 Discussion and conclusion

Only nine out of the 19 batoid species recorded for the San Matías Gulf (SMG) were found in commercial landings, all of which are frequently found in SMG (Perier et al. 2007). The exceptions are *B. brachyurops* and *B. macloviana*, whose presence seems to be sporadic, as this was the second and first record for these species in SMG, respectively. The nine landed species are endemic to South America and are exploited throughout their geographic range (Agnew et al. 2000; Cedrola et al. 2005; Massa et al. 2004; Tamini et al. 2006; Licandeo et al. 2006; Quiroz et al. 2007; Domingo et al. 2008). As a consequence of high levels of exploitation and deficient management tools, six of these species are on the IUCN red list of endangered species, categorized as vulnerable or endangered with extinction (IUCN 2010).

Atlantoraja platana S. bonapartii and *D. chilensis* are considered the main species of this fishery. Their combined relative abundance and weight were about 90% of the batoid catch, dominating commercial landings throughout the year. For *A. platana* this is the only population known in the Argentine Sea (Coller pers. obs.) and the fishery in SMG constitutes a major threat for it. For the other species, their interrelationship with individuals of the adjacent platform is not clearly established. As a consequence, these populations could also be impacted by other fisheries or restored by migrating individuals.

One particular finding of the present study was that *D. trachyderma* showed a skewed length frequency distribution towards mature individuals, and maximum lengths (about a metre) and sizes at maturity (about 40 cm) that were noticeably smaller than in other localities (Cedrola et al. 2005; Licandeo et al. 2007), which could represent a source of error. *Dipturus* spp. are commonly subject to misidentification because they often present similar external morphologies (Cedrola et al. 2005; Iglesias et al. 2010). In addition, another species of *Dipturus* (*D. argentinensis*) from the Patagonian shelf was described during the course of this study (Díaz de Astarloa et al 2008). We are not convinced that the differences between the present and previous studies can necessarily be attributed to population-level variation. Although identifications in the present work were carefully carried out, most samples were taken in fish factories, with limited time. Therefore, we cannot eliminate the possibility that some individuals, especially the smallest ones (<60 cm) could have been misidentified. A misidentification of individuals of *D. trachyderma* as *D. chilensis* could explain the skewed length frequency distribution towards mature individuals and the sex ratio shown in *D. trachyderma*. *D. argentinensis* has not been recorded in SMG since its description. For the moment, we have rejected the idea that individuals of this species may have been mixed with individuals of the other *Dipturus* species in the present study. A revision of the genus in the Southwest Atlantic could both clarify the differences between the present and previous studies and propose key characteristics to accurately discriminate between species.

Sexual segregation is a common characteristic of elasmobranch fishes (Wearmouth and Sims 2008). In the present study it was detected in *D. chilensis*, *D. trachyderma*, *B. brachyurops*, *S. bonapartii* and *A. cyclophora*, with individuals of one sex dominating commercial landings. Some of the underlying hypotheses proposed to explain this behavior are sex-based differences in activity, nutritional requirements and habitat selection (Wearmouth and Sims 2008), although information is still insufficient in these species to distinguish the possible causes. The segregation patterns of these species mean the sexes differed in their exploitation rates. While in *D. trachyderma*, *B. brachyurops*, *S. bonapartii* and *A. cyclophora* females were fished in larger numbers than males, in *D. chilesis* males were more freqeunt. Differences in the exploitation of the sexes have been suggested as a potential factor exacerbating the declines of elasmobranch populations (Steven 1933; Wearmouth and Sims 2008; Mucientes et al. 2009). For the present, however, lack of data prevents us from quantifying and exploring the possible effects that this sex-biased exploitation is having on these populations.

The survival of juveniles is suggested as the key factor for the maintenance of populations of elasmobranch fishes (Stevens et al. 2000). In the present study commercial landings were dominated by immature individuals, which in some cases exceeded 80% of the individuals landed (*D. chilensis* and *A. castelnaui*). The case of *D. chilensis* deserves particular attention because this skate is extremely vulnerable to fishing exploitation (Quiroz et al. 2011). A recent study has shown that the population growth rate is slow even in absence of fishing mortality and that the main contributing factors are the survival of juveniles and early life stages (Quiroz et al. 2011). According to their models, abundance is only maintained when the fished population is composed of mature individuals of older ages. Therefore, it is suggested that conservation actions should be focused on the regulation of the fishing mortality of juveniles (Quiroz et al. 2011). One way to mitigate the impact of removing immature individuals would be to establish a size limit for landed skates. Studies carried out in bottom trawl fisheries have shown that the survival of discarded skates reaches 50 to 60%, and can be higher depending on the species, sex, duration of the tow and codend weight (Laptikhovsky 2004; Enever et al. 2009). A size limit of 60 cm for commercial skates would considerably reduce the proportion of immature individuals in commercial landings. However, mortality rates among discards and the key factors affecting discard mortality must be examined before the value of this strategy can be assessed. In addition, other measures such us a reduction in the duration of the tow could be adopted. It is also indispensable to conduct research surveys that will allow us to assess the seasonal abundances and geographic ranges of these populations in order to quantify the impact that this fishery is having on them.

Finally, this study provided the basis for a proposal to the local government for a new logbook format to record commercial catches incorporating species-level identification. The species were selected taking into account their occurrence in commercial landings and the ease of a rapid and accurate classification by the crew on board. Five species were incorporated and, because *D. chilensis* and *D. trachyderma* are difficult to differentiate, we proposed to put both species under a common category. The new logbook format was implemented on 1 January 2010.

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