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Depletion of trophy large-sized sharks populations of the Argentinean coast, south-western Atlantic: insights from fishers' knowledge

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Globally, sharks are impacted by a wide range of human activities, resulting in many populations being depleted. Trophy large-sized sharks of the Argentinean coast, the sand-tiger *Carcharias taurus*, the copper *Carcharhinus brachyurus* and the sevengill shark *Notorynchus cepedianus* are under intense sport and artisanal fishing since the 50's decade. However, the current and historical information for the assessment of its populations status is scarce. The aim of this work was to analyze the status of conservation of these species through the gathering of expert fishermen knowledge (FK) on semi-structured interviews. Abundance variation perception between the beginning and the end of fishermen careers revealed a critical status for the species study (means variation between -77 and -90 %). Furthermore, a best day´s catch analysis reinforce this result in the case of the sand tiger shark. The school shark *Galeorhinus galeus* was included on this work with the objective of contrast FK with formal information available of catch-per-unit-effort (CPUE) time series. Both sources of information, despite are not comparable, shows declines ~ - 80%. The critical conservation situation of study species needs urgent management action, particularly for the san tiger shark which could became regionally extinct before the reaction of stakeholders occurs.

A escala global, los condrictios se encuentran severamente afectados por un amplio rango de actividades antrópicas. Actualmente una gran proporción de poblaciones se encuentran diezmadas y algunas especies son consideradas en peligro de extinción. Los tiburones de gran tamaño y de interés pesquero de la costa Argentina, el escalandrún *Carcharias taurus*, el bacota *Carcharhinus brachyurus* y el gatopardo *Notorynchus cepedianus* se encuentran bajo una intensa presión de pesca desde la década del 50. Sin embargo, la información actual o histórica sobre el estado de conservación de estas especies es muy escasa. El objetivo de este trabajo fue analizar el estado de conservación de estas especies a través de la colecta de conocimiento de pescadores expertos mediante entrevistas semi-estructuradas. La precepción de los pescadores sobre la variación en abundancia entre el principio de sus carreras y el final de las mismas, mostró un estado crítico de las especies de estudio (variación media entre -77 y -90%). Además, un análisis sobre el mejor día de capturas revela un estado particularmente crítico para el eslandrún. El cazón *Galeorhinus galeus* fue incluido en este trabajo con el objetivo de contrastar los resultados de la percepción de los pescadores con información formal disponible basada en información de Captura por Unidad de Esfuerzo. En ambas fuentes de información, si bien no son comparables, se obtuvo una declinación del 80 % en la abundancia. Adicionalmente, en este trabajo se recabo información sobre los patrones estacionales de ocurrencia de las especies (adultos y neonatos). El crítico estado de conservación de las especies de estudio requiere la aplicación de mediadas de manejo urgentes, especialmente para el escalandrún que podría extinguirse regionalmente antes de que reaccionen usuarios u organismos de manejo.

Keywords: *Carcharhinus brachyurus, Carcharias taurus*, Conservation status, Folk ecological knowledge, *Galeorhinus galeus*, *Notorynchus cepedianus*.

Introduction

Globally, sharks are impacted by a wide range of human activities, resulting in many populations being depleted and some species considered threatened with extinction (Stevens *et al*., 2000; Graham *et a*l., 2001; Baum *et al.,* 2003; Ferretti *et al.,* 2008). Large-sized sharks are particularly jeopardized due to their slow life history, low densities and large home ranges (Compagno, 1990; Cortés, 2000; Frisk *et al.,* 2001; Hutchings *et al.,* 2012). On the Argentinean coast, the group of large-sized sharks targeted by sport and artisanal fishermen comprises: the sand-tiger shark *Carcharias taurus* Rafinesque, the copper shark *Carcharhinus brachyurus* (Günther) and the broadnose sevengill shark *Notorynchus cepedianus* (Péron) (Lucifora, 2003; Cedrola *et al.,* 2011). These species are under intense sport and artisanal fishing since the 50's decade along all its range of distribution in Argentina, Uruguay and Brazil (Chiaramonte, 1998;

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Cedrola *et al*., 2011). In Argentina, there are neither historical fisheries statistics or long term studies for the assessment of its conservation status. However, an analysis of captures between 1998 and 2001 of sport and artisanal fisheries in Bahía San Blas, Argentina (40° S) and a recent ethnozoological study showed decreasing population trends (Lucifora, 2003; Barbini *et al*., 2015). Also, these species are perceived as threatened by managers and biologists and the limited knowledge about the conservation status of large-sized sharks of the south-western Atlantic was identified as one of the mayor deficiencies to guide and promote managements actions (Wohler *et al.,* 2011). On the other hand, many small- and medium-sized species, presumable more resilient to fisheries, show strong evidences of decline and most of the commercial shark species were assessed as "threatened" in the 2011 IUCN Red List of Threatened Species (*e.g.* School shark *Galeorhinus galeus* (Linnaeus), narrownose smooth-hound *Mustelus schmitti* Springer, angel sharks *Squatina guggenheim* Marini and piked dogfish *Squalus acanthias* Linnaeus) pointing out the urgent need of information about conservation status of south Atlantic large-sized sharks.

On the last decades, the relevance of ethnozoology research for biodiversity management and conservation has increasingly been recognized (Alves, 2012; Alves & Souto, 2015; Fischer *et al.* 2015). Currently, the ethnoichtiology is widely used as a tool to infer about the conservation status of fishes (*e.g.* Ainsworth *et al.,* 2008; Luiz & Edwards, 2011) as well as to gather key ecological knowledge for management (*e.g.*: migrations patterns and nursery areas) (*e.g.* Gerhardinger *et al*., 2009; Rasalato *et al*., 2010). In this sense the value and utilization of the fishermen's knowledge (FK) is growing fast (*e.g.* Mackinson & Nottestad, 1998; Fischer *et al*., 2015). This FK is distilled with years of observance over its living sources and could pass down over generations. Moreover, this source of knowledge is dynamic as it responds to changing circumstances and, therefore, has the potential management virtues of being time-sensitive, location specific and holistic (Huntington, 2000; Johannes *et al.,* 2000; Sáenz-Arroyo *et al.,* 2005a). One of the main issues of constant awareness among fishermen is the abundance status of a target species year by year. This fishermen's perception, about species abundance, have been shown to be accurate in studies were this source of information were contrasted with research data (*e.g.* Neis *et al.,* 1999). Furthermore, where long term data sets are unavailable, older fisherman's are also often the only source of information on historical changes in local marine stocks (Huntington, 2000; Johannes *et al.,* 2000).

Drawbacks in the use of FK, however, are potential bias in the information generated: responses are not neutral to informant's interests or expectations (*e.g.* it may affect regulatory measures), experience of the fishermen (*e.g.* spatial and temporal variability on experience, gears utilized, etc.) and context of which is generated (*e.g.* private interviews, workshops, etc.). Also, the design of questionnaires and a wide range of cognitive bias could influence results. Among cognitive bias, the so-called shifting-baseline syndrome (Pauly, 1995) is one of the most discussed, because could mask the magnitude of a reported declining trend depending on the age and years of experience of the reporter (*e.g.* Sáenz-Arroyo *et al.,* 2005b). The reference to judge current status shifts over time as populations/ecosystems change, reflecting people's own experience in a form of "generational amnesia" (Papworth *et al.,* 2009). Contrary, "memory illusions" could exaggerate reported trends as fishermen's reports of past catch rates may be biased towards extreme or more memorable events (Daw, 2010; O'Donnell *et al.,* 2010). To address potential bias it is necessary, (1) a systematic and rigorous methodology, including explicit establishment of the bases for identifying and selecting informants, (2) results should be contrasted with other data sources whenever possible and (3) a "rational skepticism" needs to be exercised when interpreting and applying FK, similar to any kind of scientific data (Davis & Ruddle, 2010).

The aim of this study is to evaluate the conservation status of the trophy large-sized shark species of the Argentinean coast. Semi-structured interviews were used to gather experts perceptions about possible changes in abundances of target species. The school shark *Galeorhinus galeus* was included in interviews, in order to compare fishermen's perception about its population status with previous population status estimations based on catch-per-unit-effort (CPUE) time series (Miranda & Vooren, 2003; Walker *et al.,* 2006). Additionally, fishermen reports of the best day's catch on number of individuals and the largest animal ever caught were used as another tool to infer about the conservation status of the studied species. Finally, information of seasonal occurrence of adults and neonates was gathered during interviews as a preliminary analysis of the potential use of FK to gather information about life history traits of these species.

Species background. This study comprises the largest-sized shark species targeted by sport and artisanal fisheries in the south-western Atlantic, the sand-tiger shark, copper shark, broadnose sevengill gill shark and the medium-sized school shark (Chiaramonte, 1998; Cedrola *et al.* 2011). Notwithstanding that other large-sized species (*e.g.* Smooth hammerhead *Sphyrna zygaena* (Linnaeus) and the blue shark *Prionace glauca* (Linnaeus) are occasionally caught, they are not directly targeted by the fishermen (personal observations). The most relevant information for the large-sized species for the south-western Atlantic was produced by Lucifora (2003) in regards to age and growth, reproductive biology, trophic ecology and population dynamics conducted in Bahía San Blas (40°S), Argentina (Lucifora *et al.,* 2002, 2004, 2005a, 2005b; Lucifora, 2003). Previous studies of these species include taxonomy (*e.g.* Lahille, 1928), biological studies based on occasional captures of individuals (Siccardi *et al.,* 1981; Menni & García, 1985; Menni *et al.,* 1986; Menni, 1986) and a series of works based on gillnet captures off Necochea and Quequén between 1990 and 1998 which describe fisheries and catch data (Chiaramonte, 1998). In the case of the school shark there exists a wider spectrum of studies regarding reproductive biology (Vooren, 1997; Elías *et al.,* 2004; Lucifora *et al.,* 2004), diet (Elías *et al.,* 2004; Lucifora *et al.,* 2006) and catch data analysis (Chiaramonte, 1998).

The sand-tiger shark, is a large (Lmax= 320 cm) coastal predator occurring in the north and south-western Atlantic, Mediterranean and northwest coast of Africa, South Africa, Australia and south eastern Asia (Pollard *et al.,* 1996; Compagno, 2002; Last & Stevens, 1994). On the south-western Atlantic it ranges from Rio de Janeiro (23° S, Brazil) to San Matías Gulf (41.5° S, Argentina) (Bigelow & Schroeder, 1948; Menni, 1986). The south-western Atlantic population of this species is categorized Critically Endangered (Chiaramonte *et al*., 2007) by the International Union for Conservation (IUCN). It is very susceptible to over fishing and its populations have been severely depleted in several regions of the world (Castro *et al.,* 1999; Smith & Pollard, 1999; Pollard & Smith, 2005) and has become locally extinct on some regions of the southern Brazilian coast (Vooren & Klippel, 2005).

The copper shark, is a large-sized shark (Lmax= 325 cm) distributed in the north-western, north-eastern and south-eastern Pacific, southern Australia and New Zealand, southern Africa, Mediterranean and north and south-western Atlantic (Garrick, 1982; Last & Stevens, 1994; Duffy & Gordon, 2003). On the south-western Atlantic ranges from Rio de Janeiro (23° S, Brazil) to Peninsula Valdes (43° S, Argentina) (Bigelow & Schroeder, 1948). This species is unique within the genus in inhabiting temperate rather than tropical coastal waters (Garrick, 1982) and is one of the less productive shark species, and hence potentially one of the most vulnerable ones (Cortés, 2002). It was categorized near threatened by IUCN, however, the lack of fisheries data or landings grouped with other *Carcharhinus* difficult to follow population trends (Duffy & Gordon, 2003). Despite this, in East Asia, the copper shark is part of an entire assemblage of large coastal sharks collapsed due to intensive fisheries (Duffy & Gordon, 2003).

The broadnose sevengill shark (Lmax= 300 cm) is widely distributed in temperate coastal regions around the world, except the north Atlantic and Indian Ocean. On the south-western Atlantic it is distributed from Cananéia (25° S, Brazil) to South Patagonia (55° S, Argentina) (Sadowsky, 1970; Guzmán & Campodonico, 1976). This species inhabit mostly coastal and shelf waters (Barnett *et al.,* 2010, 2012; Williams *et al.,* 2012) and consume a variety of prey including marine mammals, chondrichthyans and teleosts (Lucifora *et al.,* 2005a; Braccini, 2008). Due to its exposure to intensive inshore fisheries over most of its range and the life history traits common to large sized temperate sharks it is highly vulnerable to over fishing (Compagno, 2005), however, it was categorized Data Deficient by the IUCN Sharks Specialist Group Red List due the general lack of information (Compagno, 2005).

Finally, the school shark, *Galeorhinus galeus*, is a medium-sized (Lmax= 193 cm) shark that occurs in coastal and shelf temperate waters in the north eastern and south-eastern Pacific, north-eastern and south Atlantic, Mediterranean Sea, southern Australia and New Zealand (Last & Stevens, 1994). On the south-western Atlantic it is distributed from Cananéia (25° S, Brazil) to the San Jorge Gulf (47° S, Argentina) (Vooren, 1997; Góngora *et al.,* 2009; Góngora, 2011). Its life history is characterized by slow growth, high longevity (up to 50 years, Olsen, 1984), late age at maturity, low fecundity and low mortality (Peres & Vooren, 1991; Stevens, 1999), and thus is highly vulnerable to over fishing. In the south-western Atlantic the school shark population is subject to intensive fishing throughout its distribution with drastic declines reported (Lessa *et al*., 1999; Mateo, 2006; Walker *et al.,* 2006). In Argentina the CPUE based on trawling data has declined by around 80% during the past decade, and thus was categorized by the IUCN as Critically Endangered regionally, while elsewhere is considered vulnerable (Walker *et al.,* 2006).

Material and methods

Interviews and study site. The first goal was to identify shark fishing experts along the Argentinean coastal localities (Davies & Wagner, 2003). Sport fishing web sites, forums and consults to biologists and fishermen were used to identify the fishermen most respected by their experience and knowledge in the following localities: San Clemente del Tuyú (36.4° S), Mar del Plata (38° S), Bahía Blanca (39.1°S) and Puerto Madryn (42.7°S) (Fig. 1). The fishermen most mentioned for each locality were contacted. Interviews continues following a snowball sampling scheme (Bailey, 1994) by fishermen's recommendations of colleagues. This procedure is useful in situations where finding individuals willing to participate in the survey is a challenge (Lopes *et al.,* 1996). Surveys trips were conducted between August of 2011 and September of 2012.

Several studies (*e.g.* Mackinson & Nottestad, 1998; Huntington, 2000; Davis & Wagner, 2003; Drew, 2005; Sáenz-Arroyo *et al*., 2005a) were used as references to help design the survey and questions. The fishermen were contacted first by e-mail, telephone or seen directly on their localities (contacted on the coast or their homes) and arrangements were made to be interviewed later in person. They were interviewed in a semi-directive fashion (Huntington, 2000). Interviews were recorded and then transcribed. Before start each interview, fishermen were informed that information gathered during the interview is confidential and is used only with scientific purposes. Additionally, permission to record the interview with the informed objective of transcribe the interview was requested to each fishermen. Each person interviewed was asked about (a) area of expertise, (b) the fishing gear and period of activity and (c) shark species targeted. Then, for each species mentioned, the interviewed person was asked to freely talk about five topics in the following order: 1) seasonal patterns in catches of adults and neonates, 2) year of the best day's catch on number of individuals and the largest animal, 3) possible changes in the abundance between the beginning of their fishing activity and the last years and 4) in the case of an affirmative answer of the previous question, fishermen were asked to estimate the percentage of change (positive or negative). Finally, they were asked for names of colleagues respected for their experience and knowledge. During the interviews photos and drawings of species were available to check species identification because common names vary between localities.

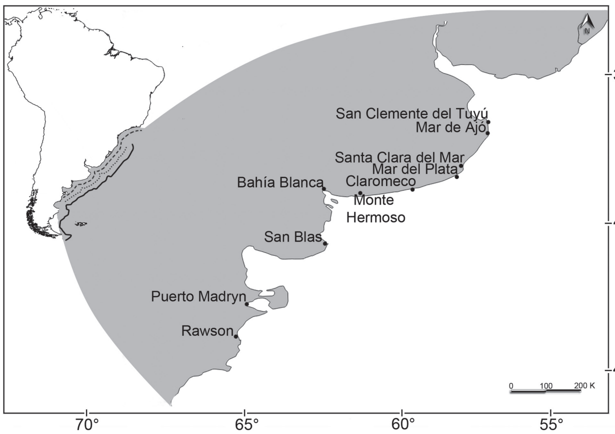

Fig. 1. Location of coastal localities and distribution range of study species in the south west Atlantic. Continuous line: *Notorynchus cepedianus*; dotted line: *Galeorhinus galeus*; dashed line: *Carcharhinus brachyurus* and *Carcharias taurus*.

Analysis. Possible relationships between fishermen's reports and the latitude of the fishing localities, age of the fishermen and type of fishing (artisanal or sport) were assessed fitting generalized linear models (GLM´s) with the R software (R Development Core Team, 2013) using the above described variables as fixed factors. In cases where fishermen were both, artisanal and sport fishing guides, were considered as artisanal.

In order to make comparable careers of fishermen, and consequently the moment of the best day's catch occurrence, we calculated a "Time index" (TI) for each species and best day's catch (on number of individuals and the largest animal), according to:

$$\mathrm{TI}=\sum_{i=1}^{N} FY - IY \,/\, RY - IY$$

where *FY* = Last year of fishing activity (2012 were assigned in the case of current fishing activity)
IY = year of initiation of fishing activity
RY= year of the best day's catches

This index simply standardize time between 0 (beginning of fishing activity) and 1 (the end of fishing activity) the fishermen's careers.

Under the assumption that on a declining population trend, the best day's catch tend to occur early on the fishermen's careers than expected by chance (*i.e.* every fishing season with the same probability of a record occurrence) for each species and best day's catch (on number of individuals and the largest animal) we used a permutation test (Manly, 1991) to evaluate if the TI means obtained were different than the expected by chance. We used a uniform distribution to randomly generate 10000 datasets of values between 0 and 1 with the number of samples equal to the number of fishermen interviewed for each species and calculate mean TI for each dataset. Finally we calculated the probability to obtain values minor or equal of each TI mean under the uniform distribution above mentioned inspecting the left-hand tail of the cumulative probability distribution.

Additionally, for each species and best day's catches TI's, a bootstrap test of 10000 random samples with replacement were used to calculate 10000 values of the bootstrap TI means. Then we calculated the probability of obtaining a mean of minor or equal to 0.5 (the record mean expected by chance during fishermen´s careers) inspecting the right-hand tail of the cumulative probability distribution of our 10000 bootstrapped mean values.

All analyses were performed with the R software (R Development Core Team, 2013).

Results

In total, three fishermen refused to be interviewed and other 29 fishermen were interviewed on coastal localities of Argentina between 36.4° S and 43.5° S on the south-western Atlantic coast during 22 days of field work (Fig. 1). The following localities were visited: San Clemente del Tuyú (36.4° S), Mar de Ajó (36.7° S), Santa Clara del Mar (37.8° S), Mar del Plata (38° S), Claromecó (38.8° S), Monte Hermoso (39° S), Bahía Blanca (39.1° S), Bahía San Blas (40.3° S), Puerto Madryn (42.7° S) and Rawson (43.5° S). Fishermen didn't recommend more than two respected colleagues (average 1,18) and age ranged between 37 and 74 years old (average = 55 years). Starting years of fishing range between 1940 to 1990 (average = 1980) and three fishermen where retired while the others remain on activity on the moment of the interview. Twenty-two fishermen were sport fishers and 10 of them work as fishing guides, other four were either artisanal fishermen and sport fishing guides and only three were exclusively artisanal fishermen. In all cases the shark fishing experience was based on "rod and reel" fishing, and additionally in the use of gillnets in the case of artisanal fishermen. Because not all fishermen declared vast experience regarding all species, 18, 26, 20 and 21 fishermen answered questions about the sand-tiger shark, copper shark, broadnose sevengill shark and the school shark, respectively.

The 92, 70, 61, and 84 % of the fishermen interviewed reported a decrease in abundance of the sand-tiger, copper, broadnose sevengill and school shark respectively, while the other reported no variation. None of the factors analyzed (latitude of the fishing localities, age of the fishermen and type of fishing, artisanal or sport) show significant influence on variations reports for the four species. The variation in abundance reported was equal or major to -50% in all cases, with the exception of one report of the -30% for the cooper shark. When fishermen reported a range of values of diminution, the lowest were considered. For the sand tiger shark, one of the 13 fishermen reported no variation in abundance and the rest agreed in a decline between 70 and 100 % (average -90%) (Table 1; Fig. 2). Furthermore, 5 fishermen report null captures during the last 5-6 shark fishing seasons. In the case of the copper sharks, variations in abundance ranged between -30 and -100 % (average = -74 %), while 6 of 20 fishermen reported no variation (Table 1; Fig. 2). Variations in abundance reported for the broadnose sevengill shark ranged between -50 and -100 % (average = -80 %), while 7 of 18 fishermen reported no variation (Table 1; Fig. 2). Finally, of the 19 informants for the school shark, 3 reported no variation, and the rest reported a range of diminution between -50 and -100 % (average -77%) (Table 1; Fig. 2).

Table 1. Number of interviews and reports of shark abundance change. Total number of fishermen's reports (N total), number of no-variation reports (N no-var. rep.), number of variation reports (N var. rep.), number of variation reports without assign a magnitude (N var. rep. with no mag.), variation range reported (Var. range -%), mean of variation reported (Var. mean -%) and mean of variation reported averaging ceros of no-variation reports (Var. mean averaging ceros -%).

Species	N total	N no-var. rep.	N var. rep.	N var. rep. with no mag.	Var. range (-%)	Var. mean (-%)	Var. mean averaging ceros (-%)
Sand tiger shark	13	1	12	2	70 to 100	90	82
Copper shark	20	6	14	3	30 to 100	74	48
Broadnose sevengill shark	18	7	11	2	50 to 100	80	55
School shark	19	3	16	5	50 to 100	77	65

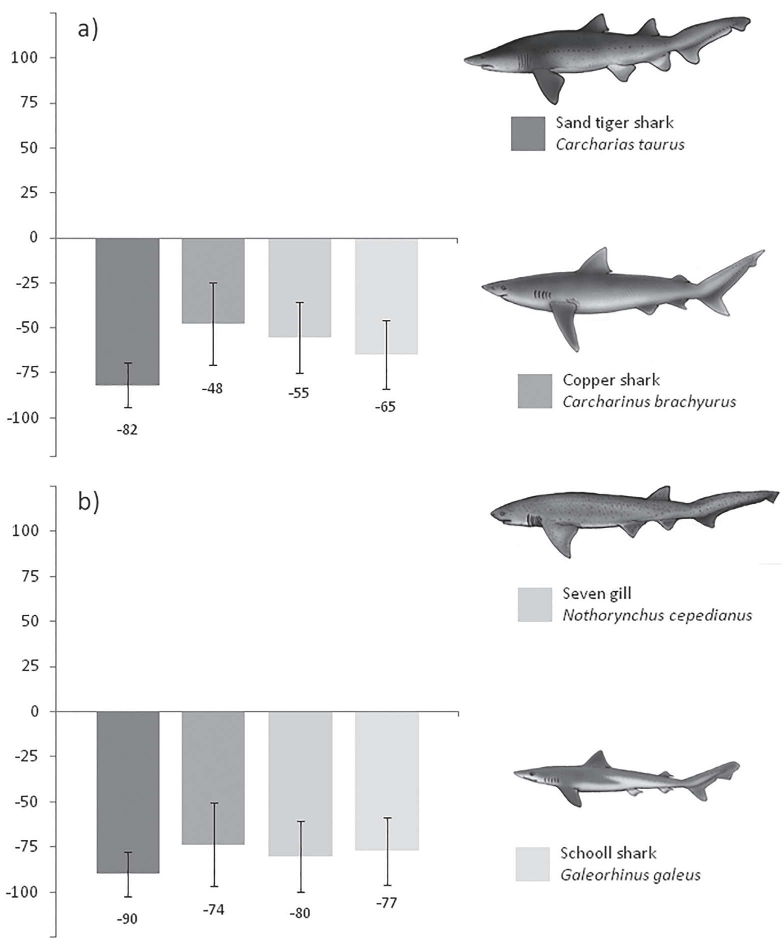

Fig. 2. Variation in abundance reported by fishermen between the beginning of their fishing activity and the last part. (a) With all reports considered and (b) with no abundance variation excluded.

The best day's catch for sand-tiger occurred on average on the first third of fishermen´s careers (Table 2). For both types of records, the largest animal ever caught and the largest catch on number of individuals, the TI means obtained were significantly lower than expected by chance trough fishermen´s careers, in the case of the permutation test. Also the probability of obtain a TI mean mayor or equal to 0.5 was significantly small (> 0.05) on the bootstrap analysis (Table 2).The best day's catch for copper and seven-gill shark occurred on average around the middle of the fishermen´s careers (TI means between 0.43 and 0.53- Table 2). The permutation test and the bootstrap analysis were non-significant in all cases. In the case of the school shark, fishermen did not register the largest captures in size and only in two cases the maximum captures on number of individuals, and thus those data were not analyzed.

Table 2. Time Index (TI) for the best day´s catch records of the largest animal ever caught and the maximum number of individuals for each species. Number of reports for each species and TI (N reports), TI mean and standard deviation (TI mean ± SD), permutation test level of significance (Permutation test pα=0.05), bootstrap probability of a TI mean => to 0.5 (Bootstrap prob. of TI mean => 0.5) and bootstrap TI mean minimum of significant magnitude. In bold are noted a significant level of probability.

Species	N reports	N reports	TI mean ± SD	Permutation test $p_{\alpha=0.05}$	Bootstrap prob.of TI mean => 0.5	Bootsrap TI mean min. for sig. level
Carcharias taurus	Largest	13	0.36 ± 0.26	**0.04**	**0.039**	0.49
	Number	12	0.31 ± 0.33	0.011	**0.029**	0.47
Carcharinus brachyurus	Largest	17	0.53 ± 0.26	0.66	0.71	0.70
	Number	12	0.43 ± 0.21	0.20	0.17	0.54
Nothorynchus cepedianus	Largest	12	0.48 ± 0.30	0.40	0.40	0.57
	Number	10	0.43 ± 0.29	0.22	0.21	0.62

Seasonal occurrence of adults and neonates. All fishermen's reported a marked seasonality for adults of all species. The sand-tiger and copper shark fishing season was reported to last between the end of the spring (November and December) up to the beginning of the autumn (March-April) with a peak of abundance on the summer (January and February), specially in the case of the sand-tiger whose presence was associated by fishermen with the warmest water temperature of the year cycle. Additionally, the copper shark was reported as occasional on October and May by 10 of 26 fishermen and both species were reported absent during colder months. In the case of broadnose sevengill and school shark a wider fishing season was reported including spring, summer and autumn, with peaks of abundance in spring (September to November), specially marked for the school shark. Additionally, half of interviewed fishermen report that it's possible to find these species on minor abundances during the colder months and in offshore areas in the case of the school shark.

Neonates of sand tigers were reported by 5 of 17 fishermen as rare events, three caught neonates on one occasion and two observe high developed embryos on one occasion. Additionally, two fishermen (one of Santa Clara del Mar and other of Bahia Blanca) reported to saw a copulation on the surface on one occasion, and fluent semen and scars adjudicated to sexual activity as frequent observations. In the case of copper sharks, 16 of 25 fishermen reported neonates and high developed embryos inside females as frequent observations. Furthermore, specific shallow channels in marsh of Bahía San Blas and Bahía Blanca were mentioned by fishermen as places where big females of copper shark give birth. In the case of broadnose sevengill sharks all fishermen from Monte Hermoso and Mar del Tuyú reported neonates as frequent captures in coastal zones on autumn. Finally, the spring peak of abundance of the school shark was associated with high frequency of females with high developed embryos inside by 13 of 21 fishermen.

Discussion

The decreasing trends found for the four species studied are alarming. In the case of the sand tiger and the school shark, the perception of abundance for fishermen of different ages and localities, either artisanal or sport, was remarkably consistent and low. Furthermore, the virtual absence of the sand tiger sharks for some fishermen on the last fishing seasons is particularly worrying. Based on our results we consider that the south western Atlantic population of the sand tiger is in a grave situation, according to previous evidence of declines trends in Argentina (Lucifora, 2003; Barbini *et al*., 2015), southern Brazil and Uruguay (Nion, 1999; Vooren & Klippel, 2005) and the quasy-extinction reported for Australian waters and the Mediterranean sea (Pollard & Smith, 2005). In the case of the school shark, our results, reinforce previous knowledge about its critical status for Argentina (Walker *et al.,* 2006) and the rest its distribution range on the south-western Atlantic (Miranda & Vooren, 2003). The information gathered for the copper and the broadnose sevengill shark were more heterogeneous, however a strong decline in abundances were evident for most of informants. Both species, vulnerable to overfishing due its life history characteristics, are supposed to be endangered trough most of their range but the lack of information restricts analysis (Duffy & Gordon, 2003), specially in the case of the broadnose sevengill shark which is considered a data deficient throughout its range, with the exception of the central California stock which is considered depleted since 1980´s (Compagno, 2005).

Currently, the four study species face intense fishing pressure (as target species or bycatch), in particular in Buenos Aires province coast were a wide range of sport and commercial fisheries (from artisanal to industrial) exist (Wohler *et al.,* 2011). This imposes a complex management situation because populations could be constantly depressed regardless if are targeted or not, since these species are vulnerable to a wide spectrum hook and line and gill net fisheries as bycacth. Furthermore, a light pressure or by-catch rates could cause major population declines for some shark species with low productivity or could continues to depress depleted populations impeding its recovery, regardless of directed fisheries were closed or well managed (Ferreti *et al*., 2010).

Trends based on the best day's catch might provide conservative estimates of the magnitude of decline as they are sensitive to the fishermen´s learning through their careers, increasing evolution and accessibility equipments (fishing gears, boats, navigation systems, fish-finders etc.), the fact that sport fishermen continuously try to overcome records and to the serial overfishing of sites. Despite these considerations, best day's catch of sand tigers occurred earlier on the fishermen´s careers than expected by chance, reinforcing the evidence that much of this population has been removed. In the case of the copper and the broadnose sevengill shark, although no significant differences between the TI means and the expected by chance were found, results were close to the minimum to be in a significant level (Table 2), with the exception of the best day catch of the largest copper shark ever caught.

Our results concur with populations declining trends found by Lucifora (2003) in Bahía San Blas between 1998 and 2001 for three study species (*i.e.* sand tiger, copper and school sharks) and a recent study based on opportunistic records from recreational fishing magazine (Barbini *et al*., 2015). Furthermore, in the case of the school shark, trends in CPUE reported in Argentina (-80% Walker *et al*., 2006) and southern Brazil (-87% Miranda & Vooren, 2003) are similar to variations in abundance reported by fishermen (declines around 80% from each study reference point). Despite that both sources of information are not comparable, both shows a strong population decline. Fishermen's perception of how abundant a species was in the past has shown to be more accurate than has commonly been thought (Neis *et al.,* 1999). For example, in the Canadian north Atlantic, fishermen's perception of declining CPUE in the cod fishery proved to be similar to trends described by official statistics. Both fishing data and fishermen's perception concurred that there was up to a 90% decline in CPUE (Neis *et al.,* 1999).

Many cognitive bias may either be masking (increasing efficiency of fishers, expansion of range of fishers, shifting baseline etc.) or exaggerating (*e.g.* memory illusions, decline in catchability of fishes, technological or health decline or ageing and crowding/interference) trends when inferring them from resource-user memory. We recognize three main biases that could be operating, (1) a gradual increase of efficiency in fishermen´s careers, (2) the shifting baseline syndrome (SBS) and (3) a crowding or interference process. (1) The evolution of equipments since the 70's (boats, beach vehicles, navigation systems and fishing gears) and the experience gathered between the first years of fishing up to the moment of interviews probably produced an increase in fishers´ efficiency. (2) Furthermore, the relatively short time scale of our study since older fishermen start fishing in the 70´s (with the exception of one fishermen who started on 1940) could be sensible to a SBS. For example, a book on shark fishing edited in Argentina on 1976 (Yaniz, 1976) has the following text "*Uncontrolled fishing of some sharks let us fear about its disappearance...*" jointly shown with a picture from December of 1943 of at least 40 dead copper shark in Playa del Faro, Mar del Plata (38° S). This anecdotal information, point out a perception of abundance diminution of large sharks previously to the experience phase of most informants of this work. (3) On the other hand, the popularization of fishing and a gradual increase of fishermen on coastal localities could exaggerate trends by a crowding or interference process. Despite the relative influence of each masking or exaggerating factors above discussed is unknown, we consider our results conservative.

Seasonal patterns reported by fishermen are in concordance with previous formal knowledge for the region (*e.g.* Menni & García, 1985; Chiaramonte, 1998; Lucifora, 2003). However, we recognize on the FK gathered on this work invaluable and specific (on time and space) information of key nursery and birth areas (inshore channels were the copper shark females give birth and nursery areas of the broadnose sevengill hark). Our results encourage further work on FK, including the fishers´ sketch maps method which is a promising tool to gather invaluable spatial-explicit information (*e.g.* Anuchiracheeva *et al.,* 2003; Gerhardinger *et al.,* 2009). Furthermore, during informal chats with fishermen, they show deep knowledge on several behavioral and ecology aspects (day *vs.* night behavior, spatial distribution discriminated on sex and/or of size class, environmental factors related with shark presence/absence, hot spots, preys, etc.) reinforcing the potential for more FK based studies. This potential is not trivial, since data required for decisions in marine resource management are frequently regarded as insufficient or inexistent, especially when considering small geographic scales (Johannes, 1998; Drew, 2005).

Finally, on this work, FK shows that could be a reliable (and low cost) source of information to contribute to the knowledge and management actions regarding study species. We gathered, systematically and rigorously, novel information about abundance trends of the some of the large and most charismatic predators of the south-western Atlantic. Furthermore, our results are similar to results based on formal information available in the case of school shark. The critical conservation situation of study species needs urgent coordinated management action involving management institutions of Brazil, Uruguay and Argentina since these countries share the home range of its populations (Chiaramonte, 1998; Lucifora *et al*. 2002, 2004; Duffy & Gordon, 2003; Irigoyen *et al*., 2015). Finally, it is remarkable the case of the sand tiger that probably could become extinct before a reaction of stakeholders and managers occur. In these sense, the regional experience of the protection program of the goliath grouper *Epinephelus itajara,* could be relevant for future conservation initiatives (www.merosdobrasil.org).

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