

**First report on a pupping area of the tope shark *Galeorhinus galeus*
(Carcharhiniformes, Triakidae) in the south-west Atlantic**

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Neonates of the tope shark *Galeorhinus galeus* are captured in sport and recreational coastal fisheries from January to April each year in Engaño Bay (42° 58'– 43° 41' S), Chubut, Argentina. The presence of these neonates is the first evidence of a pupping area for this shark in the south-west Atlantic Ocean. Knowledge of the pupping areas of chondrichthyans is important for establishing conservation measures and appropriate fishing regulations.

KEYWORDS

Engaño Bay, *Galeorhinus galeus*, neonates, Patagonia, pupping area

The tope shark *Galeorhinus galeus* (L. 1758) (Carcharhiniformes, Triakidae) is found in temperate waters and although it is considered primarily associated with coastal and bottom grounds, it can be found throughout the water column and occasionally in pelagic areas (Last & Stevens, 1994). This shark has a cosmopolitan distribution and is found in the north-west and south-west Atlantic Ocean, the north-west and south-west Pacific Ocean, the Mediterranean Sea and off South Australia and New Zealand (Compagno, 1984; Last & Stevens, 1984). In the south-west Atlantic (SWA), the species reaches its southernmost distribution at Puerto San Julian (San Cruz Province, Argentina) (Chiaramonte *et al.*, 2016). This species is considered globally as Vulnerable by the IUCN (Walker *et al.*, 2006), but according to Chiaramonte *et al.* (2016) the species should be categorized as Critically Endangered.

Galeorhinus galeus is found in southern Brazil during the austral winter months (June–September) at depths of *c.* 100 m; they leave the area in October and are absent during the spring and summer (Peres & Vooren, 1991). Vooren (1997) reported that during winter SWA populations of *G. galeus* are found in the northern extreme of their distribution area in the south of Brazil (35–34° 30' S) and that after winter, they migrate southwards and, in the

summer, reach as far as the north of Argentina (34–45° S). Several authors hypothesized that this migration could be related to travel to pupping areas supposedly found in northern Argentina (Tricas *et al.*, 1997; Vooren, 1997; Walker, 1999), but these areas have never been identified. V. Angelescu (unpubl. data) and de Buen (1950, 1952) suggested possible migration routes of *G. galeus* in the SWA and that the fisheries could be based on a single population. *Galeorhinus galeus* is a target species for several artisanal fisheries of the SWA, from Rio Grande do Sul (30° S) in Brazil (Ferreira & Vooren, 1991) to the San Jorge Gulf (46°) in Argentina (Bellisio *et al.*, 1979; Elias *et al.*, 2005). These fisheries have been described as over-exploited, although their status has not been properly evaluated (Chiaramonte, 1998; Nion, 1999; J. A. Peres, unpubl. data). The species is also vulnerable due to recreational and sport fisheries on the coastal province of Chubut, although there are no catch records.

Like other species of chondrichthyans, *G. galeus* is characterized by slow growth and high longevity (Olsen, 1984), reaching maturity at older ages (Stevens, 1999) and exhibiting low fecundity (Peres & Vooren, 1991; Stevens, 1999); consequently, the species is highly vulnerable to overfishing (Stevens, 1999).

The biological cycle of *G. galeus* remains poorly known, particularly regarding characteristics related to its reproductive habitats in the SWA. Chiaramonte (2000) used samples from commercial landings of coastal fishing fleets operating from Quequén Port (38° 32' S, 58° 42' W), Argentina, to analyse 23 pregnant females in November between the years 1992–1993 and 1997 and estimated an average length for embryos to term of 297 mm total length (L_T). Using samples collected by anglers, Lucifora *et al.* (2004) studied the reproductive biology of *G. galeus* from Anegada Bay, Buenos Aires province, Argentina (40° S, 62° W) and found females with embryos to term in October and November. In addition, Elías *et al.* (2004) assessed the longline artisanal fisheries of different areas in northern

Patagonia and noted that the *G. galeus* population that arrived at the north of Patagonia during the summer consisted mostly of mature males and females in their first and second years of maturity and did not include gravid females (Elías *et al.* 2004).

The aim of this study was to document, for the first time, the important ecological role of Engaño Bay (Chubut, Argentina) as a pupping area for *G. galeus* in the south-west Atlantic. Engaño Bay (43° S) is located in the north of Patagonia and corresponds to two oceanographic and zoogeographic subregions (Boschi, 1979; Menni & Gosztanyi 1982; Menni & López, 1984). It is considered a transition area where different water masses dominate depending on the season (Boltovskoy, 1978; Severov, 1991). The bottom of the bay is mainly composed of sand, mud and gravel (Roux & Fernández, 1997). Rocky bottoms are present in Punta León (43° 04' S, 64° 29' W) and Punta Castro (43° 24' S, 65° 05' W), at the northern and southern limits of the bay (Van der Molen & Caille, 2001). The surface water temperature ranges from 13.5 to 23° C in the summer and between 9.5 and 12.2° C in the winter. The salinity of the surface water is 31.9 and 34+ in the summer and winter, respectively (Santinelli & Esteves, 1993; Esteves *et al.*, 1997). According to Santinelli & Esteves (1993), the southern area of Engaño Bay is an estuarine area where the Chubut River contributes a significant amount of nutrients, detritus and phytoplankton.

Samples were obtained from a survey of shore recreational and sport fishing between 42 ° 58 'and 43 ° 41' in the province of Chubut during 2007, 2009, 2011 and 2012 (Figure 1). Data were obtained from capture by recreational anglers along the coast and reported catches from fishing tournaments that occurred in the area. Specimens of *G. galeus* were taken to the laboratory where they were weighed fresh with an electronic scale (0.1 g). The specimens were measured from the tip of the snout to the tip of the upper lobe of the caudal fin (L_T , mm) and the sex was identified by observing the presence or absence of claspers. Size differences between males and females were assessed by a *t*-test using previous verification of normality

and homoscedasticity. In addition, muscle tissue samples were extracted and preserved in 96% alcohol at -20° C for future genetic analyses. The criteria used to identify individuals as neonates included the size, the presence of an umbilical scar and spots on the tips of the dorsal and caudal fins like those observed in term embryos in the uteruses of pregnant females (J. M. Cuevas, pers. comm.). All specimens corresponded to young-of-the-year individuals, as identified by Lucifora (2003) from the vertebrae of specimens between 55 and 70 cm L_T . Selected specimens were deposited in the ichthyological collection of the Facultad de Ciencias Naturales, Universidad Nacional de la Patagonia San Juan Bosco, Trelew (UNPSJB-ICT: 2009/26, 2011/20, 2012/23, 2012/26, 2012/51).

In the study period, 58 neonates of *G. galeus* were collected, ranging from one individual in 2007 to 46 in 2012, of which 29 females and 29 males were recorded. The L_T of the specimens ranged between 265 and 422 mm and the total mass (M) ranged from 58 to 308 g (Table 1). The maximum size corresponded to a male $L_T = 422$ mm and $M = 284$ g, while the minimum size was $L_T = 265$ mm and corresponded to a male and female that weighed 69 and 75 g, respectively. The sex ratio was 1:1 and the size distribution followed a normal distribution (Shapiro-Wilks (unilateral) = 0.07) with a mean \pm S.D. = 344.93 mm \pm 40.81. Significant differences were not found between the mean size of males and females ($t = 0.24$, $P > 0.05$).

Records from sport and recreational anglers demonstrate that Engaño Bay represents a pupping area. Adults and juveniles of *G. galeus* are captured by sport-recreational anglers between September and April each year. However, they might also be present in the area in June, as was shown by the records of two females from Nuevo Gulf (Bovcon, 2016), both of which were in the second year of maturity (Lucifora *et al.*, 2004). According to these results, release of neonates could occur between December and February, which is accords with the

presence of adults in the catches of the recreational fishery from January to March (Bovcon, 2016).

Chiaramonte (2000) did not detect neonates in Port Quequén (1000 km north of Engaño Bay), only registered *G. galeus* females with full-term embryos in their uteruses and with an average $L_T = 297$ mm. Such results could indicate that the species may have different breeding and nursery areas, which reinforces the hypothesis that Engaño Bay could act as a specific pupping area where neonates remain and grow until reaching a large size. In addition, the specimens had umbilical scars as well as spots on the tips of the dorsal fins and the upper lobe of the caudal fin, which is observed in full-term embryos in the uteri of pregnant females (J. M. Cuevas pers. com). This suggests that the recorded specimens correspond to neonates and that adults use the Engaño Bay area also to release their young. Such findings agree with the hypothesis of Bass (1978), who suggested that Engaño Bay could correspond to a primary pupping area for *G. galeus*. According to Tricas *et al.* (1997), Vooren (1997) and Walker (1999), the migration of *G. galeus* is associated with the breeding areas that are supposedly in northern Argentina and large numbers congregate in northern Patagonia in gulfs and bays during the summer (Lucifora *et al.* (2004). The few mature individuals collected during the sampling periods, with the exception of those collected in the year 2012, indicate that Engaño Bay could potentially be a breeding area that meets the three quantitative criteria proposed by Heupel *et al.* (2007) because neonates have been found over three months and in four years during which sampling occurred. It is important to note that Engaño Bay has been described as a breeding area for other cartilaginous and bony fish (Van der Mollen & Caille, 2001; Bovcon *et al.*, 2011), thus highlighting its ecological value in the Patagonian region. Engaño Bay benefits from the high productivity of the Chubut Estuary (Santinelli & Esteves, 1993) and provides refuge and a diversity of food resources and creates suitable conditions for shark nursery areas (Castro, 1993). Other coastal areas however, may

be limited by water depth, type of habitat and trophic requirements for the species (Springer, 1967).

Based on tagging experiments, Irigoyen *et al.* (2015) supported the hypothesis that there may be a single population of the species in the South Atlantic. This would require specific management regulations, as *G. galeus* populations on a global scale are isolated from each other and thus require specific management measures for each population (Chabot, 2015). In this context, neonate *G. galeus* could become vulnerable to sport and recreational anglers from January to March due to by-catch of the recreational coastal fisheries that target elephant-fish *Callorhynchus callorhynchus* (L. 1758). Future directions should be therefore oriented to better understand the spatio-temporal dynamics of both adult and juvenile *G. galeus*. New records of *G. galeus* new-borns in the Engaño Bay area that are collected from sport and recreational coastal fisheries could provide new valuable information to complement commercial fishing records and data from research vessels. In addition, communication and interaction with fishermen regarding important biological characteristics of sharks may promote better fishing practices by stimulating catch and release practices of neonates, juveniles and adults.

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Legends for figures

Fig. 1. Putative pupping area of *Galeorhinus galeus* in Engaño Bay, Chubut, Argentina. SJG, San José Gulf; NG: Nuevo Gulf; ●, sampling sites.

Typesetter

- 1 Delete S and W from lat and long values.
- 2 Replace compass arrow with simple latin cross.

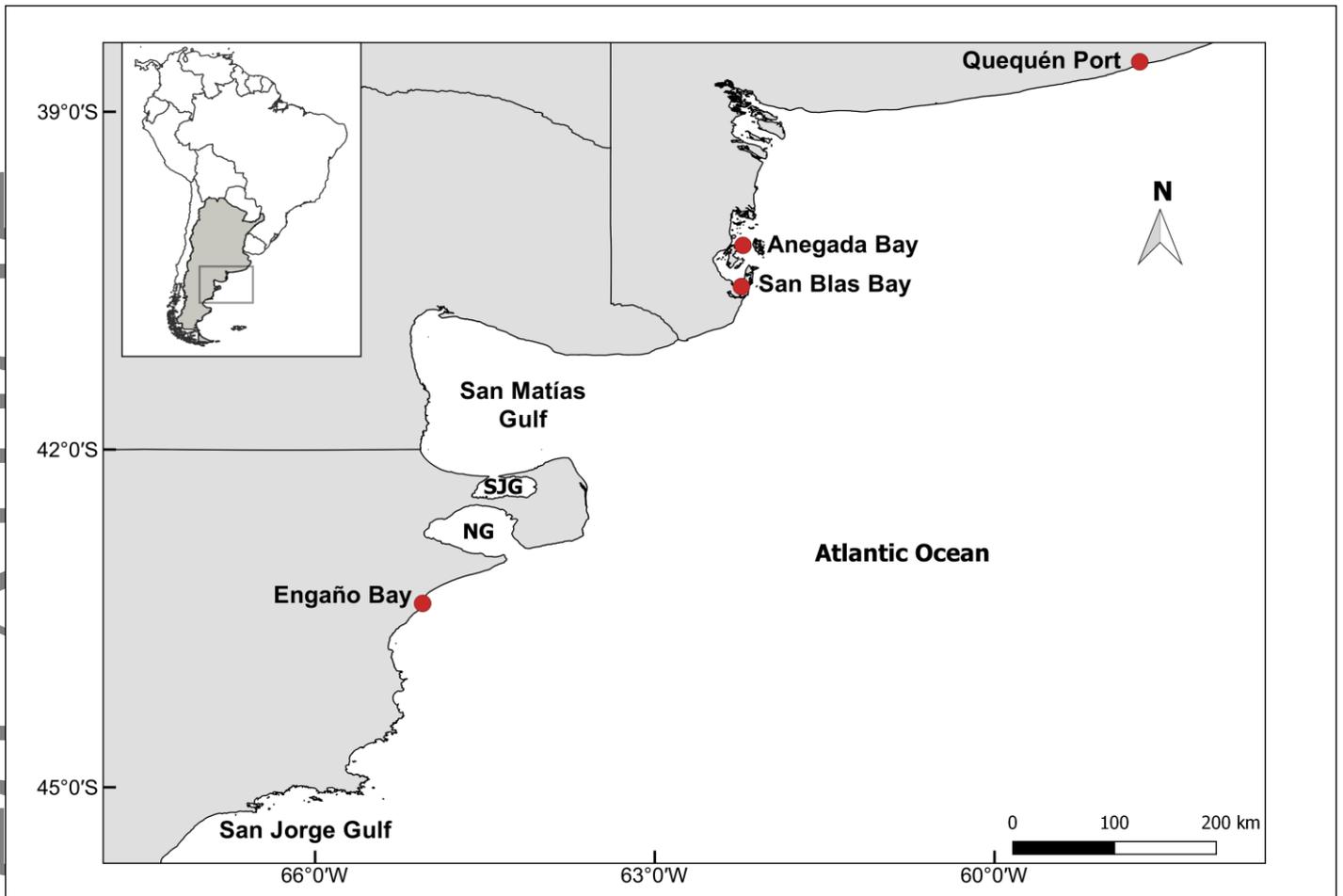


TABLE 1 Data from the neonate specimens of *Galeorhinus galeus* captured in Engaño Bay between 2007 and 2012

Year	Date	Sample size (<i>n</i>)	L_T (mm)		M_T (g)		Sex (♂/♀)	Annual L_T	Annual M_T
			Range	Mean ± S.D.	Range	Mean ± S.D.		Mean ± S.D. (range)	Mean ± S.D. (range)
2007	21/01	1	343	–	155	–	0/1	–	–

2009	22/03	3	265– 360	297 ± 55	69– 156	100 ±49	2/1	–	–
2011	13/03	4	311– 386	355 ± 31	94– 252	174 ± 64	2/2	354 ±31	178 ± 58
	20/03	4	302– 384	352 ± 35	110– 260	181 ± 61	3/1	(302– 386)	(94– 260)
2012	22/01	14	276– 326	304 ± 17	70– 128	101 ± 19	6/8	345 ± 41	165 ± 687
	05/02	3	296– 348	319 ± 26	90– 150	118 ± 30	2/1	(276– 422)	(58– 308)
	04/03	9	282– 390	350.22 ± 34	58– 228	155 ± 57	4/5		
	25/03	18	309– 422	375 ± 30	140– 308	222 ± 46	9/9		
	01/04	2	380 – 403	391 ± 16	242– 264	253 ± 15	1/1		

L_T , Total length; M_T , total mass.