

# Rare giants? A large female great white shark caught in Brazilian waters

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**Abstract** Here, we document an historical record of a large great white shark (GWS) captured in southern Brazilian waters, including morphometric measurements, basic biological data on internal organs and stomach contents. The captured shark was a female of 530 cm TL (503 cm fork-length), with an estimated total body weight of 2.5 tons. The stomach contained six shark heads, the remains of two dolphins and one teleost fish. The estimated hepatic somatic index (HSI) was 27%, and to our knowledge, represents the largest liver scientifically documented for this species to date. White sharks are known to undertake large-scale oceanic and transoceanic migrations. It is possible that the occasional records of white sharks off Brazil, previous records from Argentina and Uruguay, and an individual captured of Tristan da Cunha may be linked to migratory movements in the South Atlantic.

**Keywords** Lamnidae · Migration · Hepatic somatic index · *Carcharodon carcharias*

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## Introduction

The great white shark (GWS), *Carcharodon carcharias* (Linnaeus, 1758), is a cosmopolitan species inhabiting seas and oceans, but is most commonly found in temperate and subtropical waters (Compagno 2001). Centers of abundance are recorded in the Northeastern Pacific (Hawaii and California; Boustany et al. 2002; Weng et al. 2007; Domeier and Nasby-Lucas 2008; Jorgensen et al. 2010), Northwestern Pacific (Russia, the Republic of Korea, Japan, China, Taiwan, the Philippines and Vietnam; Nakano et al. 1987; Christiansen et al. 2014), Northwestern Atlantic (Skomal et al. 2012; Curtis et al. 2014), Australia/New Zealand (Bruce et al. 2006; Bonfil et al. 2010; Bruce and Bradford 2012; Duffy et al. 2012) and South Africa (Cliff et al. 1989; Martin et al. 2005; Koch et al. 2013). Trans-oceanic migrations have been documented between South Africa and Australia (Pardini et al. 2001; Bonfil et al. 2005), and California and Hawaii (Boustany et al. 2002; Jorgensen et al. 2010).

The occurrence of GWS in Brazil is low with ~24 documented records (Gadig 2001) and few biological data recorded for individuals from the western South Atlantic. This study documents a historical record of a GWS captured in Brazilian waters, including morphometric measurements, basic biological data on internal organs and stomach contents.

## Material and methods

The GWS was incidentally captured by artisanal fishermen using a surface gillnet (~16 cm mesh size between opposite knots) targeting teleosts and small elasmobranchs. The shark became entangled in the gillnet, and was dragged to Cananea City, Sao Paulo State, Brazil, by two fishing boats. At the landing site, the individual was measured; fork length (FL)

was recorded as the straight line distance from the tip of the snout to the center of the caudal fin, and total length (TL) was recorded as the straight line distance from the tip of the snout to the top of the upper caudal lobe (cm) and sex was determined by the presence (male) or absence (female) of claspers. A detailed series of morphometric measurements were then recorded by the lead author following the criterion of Garrick (1982; Table 1). In addition, the palatoquadrate perimeter was measured (cm), by laying a tape measure over its curvature, at the base of the teeth (cm; Randall 1973) and the dental formulae was recorded following the terminology of Applegate (1965). The largest superior tooth was selected for measurement (mm). The individual was then dissected and the mass of internal organs (liver, intestinal valve, uterus, ovary, pancreas, spleen and heart) weighed (kg) and the reproductive state of the uterus visually examined. The stomach was removed and weighed (kg) and prey were identified to the lowest taxonomic resolution possible. The total mass of the shark was estimated based on the sum of all body parts weighed to the nearest kg.

## Results

The GWS was captured 30 nautical miles off the coast (around 40 m depth) off Bom Abrigo Island, Cananeia, Southern Brazil (25°08'08"S, 47°15'05"W) on December 8th, 1992 (Figs. 1 and 2). The captured shark was a female of 530 cm TL (503 cm FL), with an estimated total body weight of 2.5 tons (Fig. 2); detailed morphometric measurements are included in Table 1. The perimeter of the jaw measured 106.5 cm and the highest superior teeth measured 48.3 mm. The dental formula was  $25/22 =$  superior 6-7:7-5 and inferior 5-6:6-5. The mass of the internal organs were as follows: liver 674 kg, stomach 200 kg, intestine valve 16 kg, uterus 13 kg, ovary 12 kg, pancreas 3 kg, heart 3 kg and spleen 1.8 kg. The estimated hepatic somatic index (HSI) was 27% (Fig. 3). The shark was not pregnant, and uterus condition did not show evidence of recent parturition. Healed bite marks were present on the left pectoral fin and flank, a possible indication of prior copulatory behavior.

The stomach contained six shark heads, the remains of two dolphins, and one teleost fish. Of the four shark heads, two belonged to the sandbar shark (*Carcharhinus plumbeus*), one to the scalloped hammerhead shark (*Sphyrna lewini*) and one to the blue shark (*Prionace glauca*; Fig. 4). There was clear evidence that the shark heads and viscera had been cut by a knife indicating these were discards from fishing boats. One dolphin was identified as a mature Atlantic spotted dolphin (*Stenella frontalis*) based on cranium features (S. Siciliano unpublished data). This individual was whole indicating a possible predation event or a scavenging incident from the net prior to the capture of the shark itself. The second dolphin and the teleost remains were not identified because of digestion state.

**Table 1** Morphometric measurements of the white shark caught off Southern Brazil following Garrick (1982)

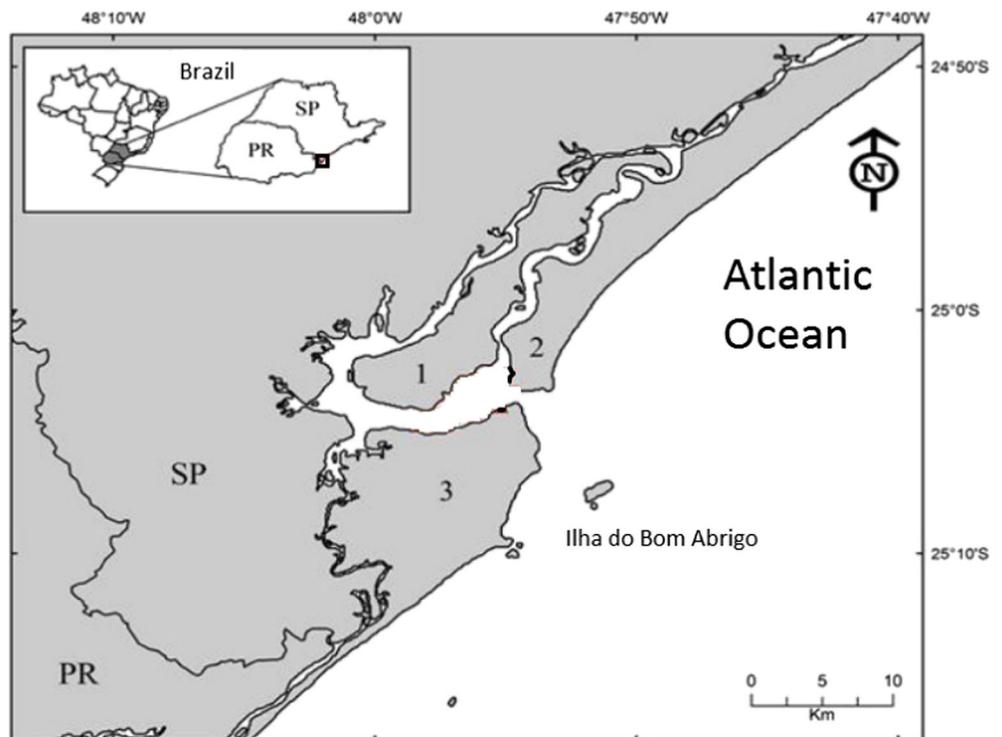
	Measures	cm	Right cm	Left cm
TL	Total Length	530.0		
	Mouth perimeter	106.5		
MOW	Mouth width	52.4		
EYL	Eye length		4.9	4.8
NOW	Nostril width		7.2	6.9
PIA	Pectoral anterior margin		107.0	107.0
PIR	Pectoral radial length		99.0	109.0
PIB	Pectoral base		39.0	41.0
P1I	Pectoral inner margin		25.0	21.0
PIH	Pectoral height		99.0	96.0
D1A	First dorsal anterior margin	75.5		
D1B	First dorsal base	52.0		
D1H	First dorsal height	60.5		
D1I	First dorsal inner margin	15.0		
D1P	First dorsal posterior margin	70.5		
D2A	Second dorsal anterior margin	17.5		
D2B	Second dorsal base	9.5		
D2H	Second dorsal height	12.0		
D2I	Second dorsal inner margin	10.2		
D2P	Second dorsal posterior margin	11.0		
PZA	Pelvic anterior margin		29.2	29.5
P2B	Pelvic base		32.0	34.0
P2H	Pelvic height		23.5	21.0
P2I	Pelvic inner margin length		14.5	15.0
CDM	Dorsal caudal margin	107.0		
CPV	Preventral caudal margin	85.5		
CPL	Lower postventral caudal margin	80.5		
CTR	Terminal caudal margin	27.1		

## Discussion

This capture of a GWS off the coast of Brazil represents the first well-documented record, whereby the individual was examined and dissected by scientists. While approximately 24 GWS have been previously recorded along the Brazilian coast (including reference to this animal; Gadig 2001), these records were based off photographic evidence and verbal accounts.

To date, most GWS records in Brazil have occurred along the coast of Espírito Santo and Rio de Janeiro States (Gadig and Rosa 1996). It was hypothesized that their occurrence in these regions was associated with a "resurgence" phenomenon, whereby seasonal upwelling brings cold waters (<18°C) into the coastal area at a point where the continental shelf is narrow (Gadig and Rosa 1996). However, the specimen examined here was captured in December just prior to the onset of summer, when sea surface temperatures are ~24°C. Previously, three large GWS (5.0, 5.3 and 5.5 m TL; one

**Fig. 1** Bom Abrigo Island, Cananeia, Southern Brazil where the white shark examined in this study was captured



female and two unknown sex) have been documented in Ceará, a region that experiences similar environmental conditions to Cananeia and is located within equatorial waters off Brazil (Gadig and Rosa 1996). At other geographical localities including the Eastern Pacific (Christiansen et al. 2014), the Western Indian Ocean (Cliff et al. 2000; Zuff et al. 2002) and off New Caledonia (Bonfil et al. 2010), GWS have also been documented to occur in tropical waters. The highest abundances of GWS at aggregation sites in California, South Africa, Australia and New Zealand, however, are typically correlated with water temperatures between 11° and 24° C (Casey and Pratt 1985; Ainley et al. 1985; Cliff et al. 1989; Bruce 1992). While satellite telemetry data has shown that GWS can inhabit an expanded thermal niche (Nasby-Lucas et al. 2009), their occurrence in warmer waters is often correlated with more transient or migratory behavior (Nasby-Lucas

et al. 2009; Cliff et al. 2000; Domeier 2012). This may suggest that white sharks caught in equatorial waters off Brazil are migratory in nature.

Although water temperature is thought to exert an influence on GWS distribution (Domeier 2012), food availability is also a strong predictor of their seasonal occurrence at aggregation sites (e.g. Martin et al. 2005; Bruce et al. 2006; Domeier and Nasby-Lucas 2008). Specifically, these aggregations are commonly related to abundances of pinnipeds (Ainley et al. 1985). Pinniped colonies (*Otaria flavescens* and *Arctocephalus australis*) are located off the Rio Grande do Sul coast in southern Brazil in austral winter and spring (Pinedo 1990; Rosas et al. 1994; Pavanato et al. 2013) and breeding colonies are located in Uruguay and Argentina (Pinedo et al. 1992; Rodríguez and Bastida 1998; Silva 2004; Pavanato et al. 2013). There have

**Fig. 2** Photographic record of the female white shark at the landing site off Southern Brazil prior to dissection. The shark measured 530 cm total length (TL) and its estimated total weight was 2.5 tons (credit: Sérgio Borges)



**Fig. 3** Photographic evidence documenting the large liver of the 530-cm total length (TL) female white shark caught off southern Brazil. The mass of the liver was 674 kg (approximately 27% of total body weight; credit: Sérgio Borges)



been no observations of GWS at these sites, and bite wounds on seals have not been recorded.

GWS undergo a distinct ontogenetic diet shift from consuming teleost prey as juveniles to a diet dominated by elasmobranchs, pinnipeds and whales during sub adult and adult life stages (Cliff et al. 1989; Hussey et al. 2012). While they are commonly observed directly preying on pinnipeds (Martin et al. 2005; Brown et al. 2010), they are also known scavengers, and have been reported to opportunistically feed on dead whales in certain areas of their range (Carey et al. 1982; Long and Jones 1996; Dicken 2008). The occurrence of fishing discards in the stomach contents of this GWS caught off Brazil indicates an opportunistic scavenging feeding behavior. The finding of an intact dolphin in the stomach may suggest a direct predation event or scavenging of this individual from the net prior to capture. This agrees with previous work that has documented dolphins in the diet of GWS (e.g. Cliff et al. 1989, Adams et al. 1994; Hussey et al. 2012).

The exceptionally large liver size of this animal, to our knowledge, represents the largest liver scientifically

documented for this species to date. The estimated HSI value of 27% was higher than values of 14.6 to 22.7% for large GWS captured in the northwest Atlantic, measuring 425 to 463 cm FL (Kohler et al. 1996). It is plausible that the large liver size indicates this animal had built up reserves prior to the gestation period and was preparing to mate, which is further supported by the bite marks recorded on the pectoral fin and flank. Alternatively, a large liver has been proposed as a mechanism to fuel long distance migrations (Del Raye et al. 2013).

GWS are known to undertake large-scale oceanic and transoceanic migrations (Bonfil et al. 2005, 2010; Domeier and Nasby-Lucas 2008; Jorgensen et al. 2010). It is possible that these occasional records of GWS off Brazil, previous records from Argentina and Uruguay (Siccardi et al. 1981; Ximenes 1962) and an individual captured of Tristan da Cunha (Andrew et al. 1995) may be linked to migratory movements in the South Atlantic. Alternatively, Brazil falls within the latitudinal distribution of global white shark populations (Christiansen et al. 2014), which may suggest GWS do occur in the region but their movements and occurrence are

**Fig. 4** Stomach contents of the female white shark caught off southern Brazil; retrieved heads of three species of sharks; *Sphyrna lewini*, *Carcharhinus plumbeus* and *Prionace glauca* and others materials (credit: Sérgio Borges)



conspicuous. For example, while GWS were originally considered rare in Florida waters (Springer 1939; Clark and von Schmidt 1965), they are now relatively common in the North Atlantic with a known seasonal distribution from Nova Scotia, Canada (McPherson and Myers 2009) to Florida and the Gulf of Mexico (Curtis et al. 2014). Equally, basking sharks (*Cetorhinus maximus*) were considered rare in tropical latitudes until the application of telemetry to track their large-scale movements (Skomal et al. 2004). It is, therefore, plausible that GWS do occur in Brazilian waters on a more regular basis than is currently known. More directed studies are needed in the South Atlantic to determine if these occurrences of GWS off Brazil are rare or not.

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## References

- Adams DH, Mitchell ME, Parsons GR (1994) Seasonal occurrence of the white shark, *Carcharodon carcharias*, in waters off the Florida west coast, with notes on its life history. *Mar Fish Rev* 56:24–28
- Ainley DG, Henderson RP, Huber HR, Boekelheide RJ, Allen SG, McElroy TL (1985) Dynamics of white shark/pinniped interactions in the Gulf of the Farallones. *Mem S Calif Acad Sci* 9:109–122
- Andrew TG, Hecht T, Heemstra PC, Lutjeharms JRE (1995) Fishes of the Tristan da Cunha group and Gough Islands, South Atlantic Ocean. *Ichthyol Bull*, 63
- Applegate SP (1965) Tooth terminology and variation in sharks with special reference to the sand shark, *Carcharias taurus* Rafinesque. *Contr Sci* 86:1–18
- Bonfil R, Meyer M, Scholl MC, Johnson R (2005) Transoceanic migration, spatial dynamics, and population linkages of white sharks. *Science* 310:100–103
- Bonfil R, Francis MP, Duffy C, Manning MJ, O'Brien SO (2010) Large-scale tropical movements and diving behavior of white sharks *Carcharodon Carcharias* tagged off New Zealand. *Aquat Biol* 8: 115–123
- Boustany AM, Davis SF, Pyle P, Anderson SD, Le Boeuf BJ, Block BA (2002) Expanded niche for white sharks. *Nature* 415:35–36
- Brown AC, Lee DE, Bradley RW, Anderson S (2010) Dynamics of white shark predation on pinnipeds in California: effects of prey abundance. *Copeia* 2010:232–238
- Bruce BD (1992) Preliminary observation on the biology of the white shark, *Carcharodon carcharias*, in South Australian waters. In J. G. Pepperell (Editor), *Sharks: biology and fisheries*. *Aust J Mar Fresh Res* 43: 1–11
- Bruce BD, Bradford RW (2012) Habitat use and spatial dynamics of juvenile white sharks, *Carcharodon carcharias*. In Domeier M (ed) *Global perspectives on the biology and life history of the Great White Shark*. CRC Press, pp. 225–70
- Bruce BD, Stevens JD, Malcolm H (2006) Movements and swimming behaviour of white sharks (*Carcharodon carcharias*) in Australian waters. *Mar Biol* 150:161–172
- Carey FG, Kanwisher JW, Brazier O, Gabrielson G, Casey JG, Pratt Jr HL (1982) Temperature and activities of a white shark, *Carcharodon carcharias*. *Copeia* 2:254–260
- Casey JG, Pratt HA Jr (1985) Distribution of the white shark (*Carcharodon carcharias*) in the western North Atlantic. *Mem S Calif Acad Sci* 9:2–14
- Christiansen HM, Lin V, Tanaka S, Velikanov A, Mollet HF (2014) The last frontier: catch records of white sharks (*Carcharodon carcharias*) in the northwest Pacific Ocean. *PLoS One* 9(4):e94407
- Clark E, von Schmidt K (1965) Sharks of the central Gulf coast of Florida. *Bull Mar Sci* 15:13–83
- Cliff G, Dudley SFJ, Davis B (1989) Sharks caught in the protective gill nets off Natal, South Africa. II. The great white shark *Carcharodon carcharias*. *S Afr J Mar Sci* 8:131–144
- Cliff G, Compagno LJV, Smale M, van der Elst RP, Wintner SP (2000) First records of white sharks, *Carcharodon carcharias*, from Mauritius, Zanzibar, Madagascar and Kenya. *S Afr J Sci* 96:365–367
- Compagno LJV (2001) *Sharks of the World. An annotated and illustrated catalogue of the shark species known to date. Vol 2. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes)*. FAO Species Catalogue Fisheries Purposes 2(1):269
- Curtis TH, McCandless CT, Carlson JK, Skomal GB, Kohler NE et al (2014) Seasonal distribution and historic trends in abundance of white sharks, *Carcharodon carcharias*, in the western north Atlantic Ocean. *PLoS One* 9(6):e99240
- Del Raye G, Jorgensen SJ, Krumhansl K, Ezcurra JM, Block BA (2013) Travelling light: white sharks (*Carcharodon carcharias*) rely on body lipid stores to power ocean-basin scale migration. *Proc R Soc Ser B-Bio* 280:20130836
- Dicken ML (2008) First observations of young of the year and juvenile great white sharks (*Carcharodon carcharias*) scavenging from a whale carcass. *Mar Fresh Res* 59:596–602
- Domeier M (2012) *Global perspectives on the biology and life history of the great white shark*. CRC Press, Boca Raton
- Domeier M, Nasby-Lucas N (2008) Migration patterns of white sharks *Carcharodon carcharias* tagged at Guadalupe Island, Mexico, and identification of an eastern Pacific shared offshore foraging area. *Mar Ecol Prog Ser* 370:221–237
- Duffy CA, Francis M, Manning MJ, Bonfil R (2012) Regional population connectivity, oceanic habitat, and return migration revealed by satellite tagging of white sharks, *Carcharodon carcharias*, at New Zealand aggregation sites. Domeier ML (ed) *Global Perspectives on the Biology and the Life History of the White Shark*, CRC Press, Editors, pp 301–318
- Gadig OBF (2001) *Tubarões da costa brasileira*. PhD thesis. Universidade Estadual Paulista, Rio Claro, Brazil
- Gadig OBF, Rosa RS (1996) Occurrence of the white shark along the Brazilian coast. In: Klimley AP, Ainley DG (eds) *Great white sharks: the biology of Carcharodon carcharias*. Academic Press, San Diego, CA, pp 347–350
- Garrick JAF (1982) *Sharks of the genus Carcharhinus*. NOAA Tech Rep NMFS Circular 445:1–194
- Hussey NE, McCann HM, Cliff G, Dudley SFJ, Wintner SP (2012) Size-based analysis of diet and trophic position of the white shark, *Carcharodon carcharias*, in South African waters. In: Domeier ML (ed) *Global perspectives on the biology and life history of the great white shark*. CRC Press, Boca Raton, pp 27–49
- Jorgensen SJ, Reeb CA, Chapple TK, Anderson A, Perle C, Van Sommeran SR, Fritz-Cope C, Brown AC, Klimley AP, Block BA (2010) Philopatry and migration of Pacific white sharks. *Proc Biol Sci* 277:679–688
- Koch A, O'Riain MJ, Mauff K, Meyer M, Kotze D, Griffiths C (2013) Residency, habitat use and sexual segregation of white sharks, *Carcharodon carcharias*, in False Bay, South Africa. *PLoS One* 8(1):e55048
- Kohler NE, Casey JG, Turner PA (1996) Length-length and length-weight relationships for 13 shark species from the Western North

- Atlantic. NOAA Technical Memorandum NMFS-NE-110. <http://www.nefsc.noaa.gov/publications/tm/tm110/tm110.pdf>; (accessed may 2016).
- Long D, Jones RE (1996) White shark predation and scavenging on cetaceans in the eastern North Pacific ocean. In: Ainley DG, Klimley AP (eds) *The biology of carcharodon carcharias*. Academic Press, Great White Sharks, pp 293–307
- Martin RA, Hammerschlag N, Collier RS, Fallows C (2005) Predatory behaviour of white sharks (*Carcharodon carcharias*) at Seal Island, South Africa. *J Mar Biol Assoc UK* 85:1121–1135
- McPherson JM, Myers RA (2009) How to infer population trends in sparse data: examples with opportunistic sighting records for great white sharks. *Divers Distrib* 15:880–890
- Nakano H, Nakaya K (1987) Records of the white shark *Carcharodon carcharias* from Hokkaido, Japan. *Jpn J Ichthyol* 33:414–416
- Nasby-Lucas N, Dewar H, Lam CH, Goldman KJ, Domeier ML (2009) White shark offshore habitat: a behavioral and environmental characterization of the eastern Pacific shared offshore foraging area. *PLoS One* 4(12):e8163
- Pardini AT et al (2001) Sex-biased dispersal of great white sharks. *Nature* 412:139–140
- Pavanato H, Silva KG, Estima SC, Monteiro DS, Kinas PG (2013) Occupancy dynamics of South American Sea-Lions in Brazilian Haul-outs. *Braz J Biol* 73(4):855–862
- Pinedo MC (1990) Ocorrência de pinípedes na costa brasileira. *Garcia de Orta, Sér Zool* 15(2):37–48
- Pinedo MC, Rosas FCW, Marmontel M (1992) Cetáceos e Pinípedes do Brasil: uma revisão dos registros e guia para identificação das espécies. UNEP/FUA, Manaus, Brazil
- Randall JE (1973) Size of the great white shark (*Carcharodon*). *Science* 181:169–170
- Rodríguez D, Bastida R (1998) Four hundred years in the history of pinniped colonies around Mar del Plata. *Argentina Aquat Conserv Mar Freshw Ecosys* 8:721–735
- Rosas FCW, Pinedo MC, Marmontel M, Haimovici M (1994) Seasonal movements of South American sea lion (*Otaria flavescens*, Shaw) off the Rio Grande do Sul coast, Brazil. *Mammalia* 58:51–59
- Siccardi E, Gosztony AE, Menni RC (1981) La presencia de *Carcharodon carcharias* e *Isurus oxyrinchus* em el mar Argentino Chondrichthyes, Lamniformes. *Physis Sec A* 39:55–62
- Silva KG (2004) Os Pinípedes no Brasil: Ocorrências, Estimativas Populacionais e Conservação. Ph.D. Thesis. Fundação Universidade Federal do Rio Grande, Rio Grande, Brazil
- Skomal GB, Wood G, Caloyianis N (2004) Archival tagging of a basking shark, *Cetorhinus maximus*, in the western North Atlantic. *J Mar Biol Assoc UK* 84(04):795–799
- Skomal GB, Chisholm J, Correia SJ (2012) Implications of increasing pinniped populations on the diet and abundance of white sharks off the coast of Massachusetts. *Global Perspectives on the Biology and Life History of the White Shark*, CRC Press, pp 405–418
- Springer S (1939) The great white shark (*Carcharodon carcharias*) in Florida waters. *Copeia* 1939:114–115
- Weng K, Boustany A, Pyle P, Anderson S, Brown A, Block B (2007) Migration and habitat of white sharks (*Carcharodon carcharias*) in the eastern Pacific Ocean. *Mar Biol* 152:877–894
- Ximenes I (1962) Notas sobre elasmobranchios. I. Quadro sistemático y sinonímico provisional de los selaceos de la costa uruguaya. *Rev Inst Invest Pesq* 1:35–44
- Zuff M, Van Grevelinghe G, DeMaddalena A, Storai T (2002) Records of the white shark, *Carcharodon carcharias* (Linnaeus, 1758), from the Western Indian Ocean. *S Afr J Mar Sci* 98:347–349