

New records of neonatal and juvenile whale sharks (*Rhincodon typus*) from the Indian Ocean

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Abstract The finding of neonatal whale sharks from Northern Indian Ocean waters off of Pakistan and Bangladesh and the description of several very small whale sharks from around Seychelles during the last few years are reported. These findings are discussed in relation to published reports of growth rates, the areas of occurrence and segregation by sex, and the behaviour of very young whale sharks, which are key factors in their conservation management.

Keywords Behaviour · Habitat · Philopatry · Growth rate · Pakistan · Bangladesh · Seychelles

Introduction

Since 1986, the number of records detailing the occurrence of whale shark, *Rhincodon typus*, has risen dramatically from the 320 records collated by Wolfson (1986). Globally, a number of areas are now known to have seasonal populations of whale sharks and most of these populations comprise sharks from 3 to 12 m in size. These include studies from the Sulu Sea, Asia (Eckert et al. 2002), Ningaloo in Western Australia (Taylor 1989; Taylor 1994; Meekan et al. 2006), South Africa (Beckley et al. 1997), Belize (Heyman et al. 2001), Sea of Cortez (Eckert and Stewart 2001), La

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Paz, Mexico (Clarke and Nelson 1997), the Gulf of Mexico (Hoffmayer et al. 2005; Hueter et al. 2005) and from the Indian Ocean (Anderson and Ahmed 1993; Rowat 1997; Pravin 2000; Hanfee 2001) including Pakistan (Gore, Hussain, Kiani, Ormond, personal observation). While the number of occurrences has increased there is, however, concern that these populations are decreasing in size as noted from areas with targeted fisheries (Pravin 2000; Hanfee 2001) and more recently from areas where there have never been targeted fisheries (Meekan et al. 2006; Bradshaw et al. 2007). Despite an increase in the known areas of occurrence, very few records exist of neonatal whale sharks or juveniles <3 m in length. This is of particular concern in the development of national and regional conservation initiatives as potential pupping and nursery areas may unknowingly be impacted by anthropogenic activities. The paucity of such information makes the reporting of any such sightings valuable.

The first discovery of a live and almost fully developed embryonic whale shark was from an egg case trawled from a depth of 57 m in the Gulf of Mexico (Breuer 1954; Baughman 1955). This 35 cm total length (TL) embryo was found to have absorbed a large mass of yolk into the abdomen thought sufficient to support the young shark for some time (Reid 1957; Garrick 1964). Wolfson described a further seven juvenile whale shark specimens ranging in size from 55 to 93 cm TL (Wolfson 1983), all caught in pelagic purse seine fishery operations. Three were found in the Atlantic and four in the Pacific oceans where the sea bed ranges from 2600 m to 4750 m. Three of the specimens, ranging from 55 to 63 cm TL and had a faint vitelline scar marking the attachment of the yolk-sac that disappears within a few months of birth in other elasmobranchs (D'Aubrey 1964). Wolfson also remarked that while her description of the seven juvenile sharks helped to provide information on the size at birth, there were no records of sharks between 1 and 4 m TL (Wolfson 1983). The capture in 1995 of a gravid female shark off of Taiwan (Joung et al. 1996) confirmed that this species is ovoviparous, retaining the lecithotrophic young within the uteri allowing further development. Of the three size classes of prenatal sharks recorded, the largest (58 to 64 cm TL) was free-swimming and without a yolk-sac but did exhibit a vitelline scar, thus the authors suggested that these prenates were ready to be birthed. There are few other reports of very young whale sharks: one was a

61 cm TL specimen found alive in the stomach of a blue marlin, *Makaira mazara*, off Mauritius in 1993 (D. Goorah, personal communication and cited in Colman 1997). Two others were reported from the tropical Atlantic (Kukuyev 1995), one trawled from water deeper than 2000 m and the other in the stomach of a blue shark, *Prionace glauca*. In 1998, 16 juveniles of about 1 m were reported to be swimming with a whale shark of 5.5 m off Vizhinjam, India (Krishna-Pillai 1998) and a similar occurrence was reported from Ningaloo, Western Australia, with 14 young whale sharks (Taylor 1994).

Opportunistic discoveries of specimens of neonatal whale sharks were made by researchers involved in marine programmes in Pakistan and Bangladesh during interviews with local fishermen and fishing authorities. In addition, we also documented the findings of several juveniles measuring less than 3 m TL from around Seychelles. In Pakistan during a survey of the Balochistan coast in February 2006, a research team from the Cetacean Conservation Pakistan project conducted interviews with Fishing Authorities and were told of the capture of two neonatal whale sharks. The sharks had been caught in 2000 in fishing nets off of Ormara, on the Balochistan coast, Pakistan. The sharks were captured by gill nets fishing in the top 100 m in an area of more than 200 m depth at position 25°02'N, 64°55'E, about 10 km offshore of the Ormara headland. The area has a steeply shelving sea-bed with the 1000 m depth contour only 10 km away. Fishers recognized the distinctive markings of the two small sharks as whale sharks and on returning to land reported their find. One of the sharks was preserved in formalin by the Fisheries Department, Omara (Fig. 1a,b), while the fate of the other specimen is not known. Further interviews with the fishermen concluded that while large whale sharks had been seen in the area at the time of capture (2000), few were now seen. The fishers also reported that the very small size of the two neonatal whale sharks caught was unique in their experience. The pup preserved was a 58.6 cm TL male (Fig. 1a) and the width across the head by the eye sockets was 9.0 cm (Fig. 1b). No yolk-sac was present and the presence of a vitelline scar could not be confirmed. Dissection of the specimen was not possible.

In Bangladesh the Marine Life Alliance, Comilla, was informed of the capture of an unusually small whale shark in March 2006. The specimen had been

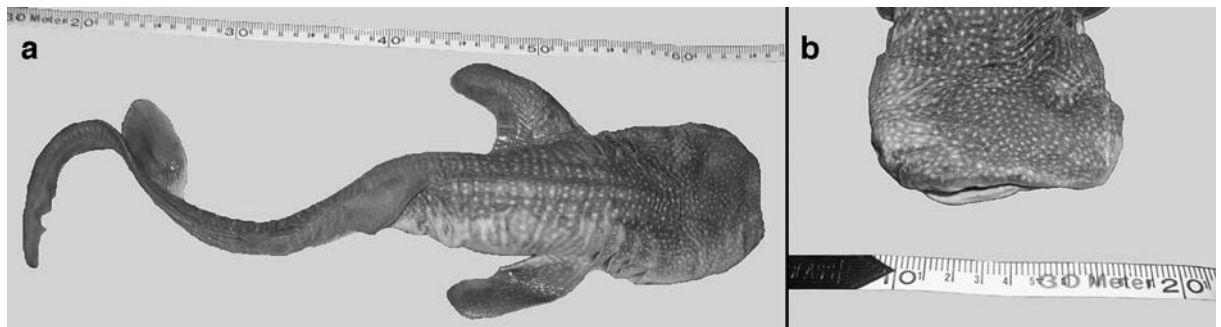


Fig. 1 The preserved neonatal whale shark specimen from Balochistan, Pakistan, **a** showing TL against a tape measure in centimeters and **b** showing head

seen at the local fish market at the town of Cox's Bazar but by the time researchers arrived, the specimen had been sold. Interviews with the fishers revealed that this pup had been caught during a fishing expedition from 15–17 March 2006, in a set bag-net 140 km offshore of the town of Cox's Bazar. The specimen was already dead when the net was recovered and was measured at 1.13 m TL. The area where the net was set was in shallow waters of 10 to 20 m depth but was close to the 30 m contour where the sea bed falls steeply to depths of over 100 m.

In the south western Indian Ocean, the Marine Conservation Society Seychelles have recorded three sightings of <3 m whale sharks off of Seychelles. The first was c.a. 1.5 m in September 1998, off of N.E. Mahe (personal observation Rowat); a second pup of 1.8 m was recorded by aerial survey off of S.W. Mahe in October 2005, the length being confirmed by reference to an object measured shortly afterwards; the third sighting of a <2 m pup was in May 2007, off of Isle Farquar (personal observation Henn). A fourth anecdotal record of a pup of c.a. 2.5 m was reported from a diving trip off of N.W. Mahe in December 2006.

As noted above, of live-born whale sharks, only nine post-natal and no neonatal sharks have been reported previously. The large number of adult whale shark aggregations known from the Indian Ocean (Taylor 1989; Anderson and Ahmed 1993; Taylor 1994; Beckley et al. 1997; Hanfee 1997; Rowat 1997; Pravin 2000; Meekan et al. 2006) would suggest that there should be a population of neonatal sharks somewhere in this region. The discovery off of Pakistan of a 58.6 cm free-swimming neonatal whale shark is important as it is the first for this area and is also the first indication that the species births in the Northern Indian Ocean. The capture from Bangladesh is also the

first record of a neonatal whale shark from the Bay of Bengal. It is of note that this shark was captured in March while the Pakistan pup was taken in February. In a survey of organizations involved in whale shark activities and research, both India and Bangladesh indicated that January to March were peak months of whale shark occurrence (Rowat 2007). The Indian whale shark fishery, which closed in 2001, had been particularly active from March to May off the north-west coast of Gujarat (Pravin 2000; Hanfee 2001) confirming that high numbers of whale sharks were present throughout the Northern Indian Ocean during this season.

Both of these new neonatal captures appear to have been from relatively shallow waters, similar to the trawled aborted embryo reported by Breur (Breuer 1954). This differs with the depths from which the juveniles described by Wolfson (1983) and Kukuyev (1995) had been caught. As these latter captures were by purse-seine, which is a wall of net extending from the surface to 100–140 m, the actual depth of capture is similar. All the neonatal captures were very close to deep water as in the two reports described here, or were made over deep water (Wolfson 1983; Kukuyev 1995), suggesting that neonatal whale sharks frequent generally deeper waters than their older conspecifics.

Similar to the smallest whale shark caught off of Pakistan, the largest was also taken near Karachi in November 1947, measuring 12.65 m (Wood 1990). Such large sharks merit attention but it is to be expected that the catch of neonatal whale sharks, being of little commercial value, could easily go unreported. A search of public reports revealed that a pup had been caught in India off of the south-west coast of Vizhinjam, Kerala (Anonymous 2002). The 95 cm pup was caught in a net in December 2002 and

given to the Central Marine Fisheries Research Institute (CMFRI) at Thiruvananthapuram, where it survived in their aquarium for only a day. The smallest recorded whale shark previously had been a 3.15 m specimen caught off of the south-east coast of Mandapam (Nammalvar 1986 cited in Pravin 2000).

Neonatal whale sharks are thought to have limited swimming abilities compared to juveniles and adults (Martin 2007). Neonatal whale sharks have an elongated body with a strongly heterocercal caudal fin (Garrick 1964; Wolfson 1983; Kukuyev 1995) very similar to neonatal tiger sharks, *Galeocerdo cuvier*, which have an inefficient anguilliform swimming stroke (Branstetter et al. 1987), thus the new records of pups of <1 m TL in the Northern Indian Ocean may indicate that this region is a pupping ground. What little is known about the post-natal development of whale sharks comes from aquarium-reared pups from the Taiwanese litter. One showed growth rates over 3 years and 2 months from 60 cm to 3.7 m TL, a growth rate of 97.8 cm per annum (Nishida 2001). Another pup from this litter grew from 60 cm to 1.39 m in 120 days before dying of septicaemia (Chang et al. 1997), a potential first year growth rate of 2.40 m per annum; this shark did not eat for the first 17 days in captivity despite swimming constantly, supporting Wolfson's (1983) and Garrick's (1964) suggestion about the yolk-sac reserve. As such, and in view of the somewhat limited swimming capacity of neonates, juveniles of <3 m are likely to be fairly close to their natal areas.

A number of shark species have been shown to exhibit philopatry at various times in their life-cycle (Merson and Pratt 2001; Pratt and Carrier 2001; Sims et al. 2001; Hueter et al. 2004). The aggregation of whale sharks in specific areas has allowed the implementation of mark and recapture studies that are beginning to show that this species also exhibits predominantly sex and age specific philopatry, largely of juvenile males (Arzoumanian et al. 2005; Meekan et al. 2006; Graham and Roberts 2007; Rowat and Gore 2007). In a recent study in the Gulf of Arta off of Djibouti, a group of whale sharks were documented that were mainly male and small, 47% <4 m TL (Rowat et al. 2006) which further supports segregation by age (size) and sex in this species.

The lack of previous records for the 1 to 4 m size class from the Indian Ocean is surprising given the known number of aggregation sites in the region. The

absence of this size class may be due to inadequacies in reporting and data recording across this very large area. If the absence of this size class reflects the actual distribution, this may be an artefact of predator avoidance behaviour by these small, defenceless sharks staying out of danger at deeper depths, and so not easily found. Alternatively, this could be a result of maternal natal philopatry with respect to pupping grounds as found in other shark species (Castro 1993; Holland et al. 1993; Simpfendorfer and Milward 1993; Kohler and Turner 2001; Hueter et al. 2004), which may then limit the distribution of these smaller sharks.

Whatever the reason for the lack of sightings of both neonatal whale sharks and the size class of 1 to 4 m (Wolfson 1983), the identification and recording of these individuals may well be key to the conservation of this species on a regional and global scale.

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References

- Anderson RC, Ahmed H (1993) Shark fisheries of the Maldives. Ministry of Fisheries and Agriculture, Male
- Anon (2002) Captured whale shark dies at aquarium. The Hindu, Chennai, Madras. <http://www.thehindu.com/2002/12/28/stories/2002122801700300.htm>
- Arzoumanian Z, Holmberg J, Norman B (2005) An astronomical pattern-matching algorithm for computer-aided identification of whale sharks *Rhincodon typus*. *J Appl Ecol* 1365–2664
- Baughman JL (1955) The oviparity of the whale shark, *Rhineodon typus*, with records of this and other fishes in Texas waters. *Copeia* 1:54–55
- Beckley LE, Cliff G, Smale MJ, Compagno LJ (1997) Recent strandings and sightings of whale sharks in South Africa. *Environ Biol Fish* 50:343–348
- Bradshaw CJA, Mollet HF, Meekan MG (2007) Inferring population trends for the world's largest fish from mark-recapture estimates of survival. *J Anim Ecol* 76:480–489
- Branstetter S, Musick JA, Colvocoresses JA (1987) A comparison of the age and growth of the tiger shark, *Galeocerdo cuvieri*, from off Virginia and from the northern Gulf of Mexico. *Fish Bull* 85:269–279
- Breuer JP (1954) The littlest biggest fish. *Texas Game Fish* 12:29
- Castro JI (1993) The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the southeastern United States. *Environ Biol Fish* 38:37–48

- Chang WB, Leu MY, Fang LS (1997) Embryos of the whale shark, *Rhincodon typus*, early growth and size distribution. *Copeia* 2:444–446
- Clarke E., Nelson DR (1997) Young whale sharks, *Rhincodon typus*, feeding on a copepod bloom near La Paz, Mexico. *Environ Biol Fish* 50:63–73
- Colman JG (1997) A review of the biology and ecology of the whale shark. *J Fish Biol* 51:1219–1234
- D'Aubrey JD (1964) Preliminary guide to the sharks found off the east coast of Africa. Oceanographic Research Institute, Durban
- Eckert S, Dolar L, Kooyman G, Perin W, Rahman A (2002) Movements of whale sharks, (*Rhincodon typus*), in South East Asian waters as determined by satellite telemetry. *J Zool* 257:111–115
- Eckert S, Stewart B (2001) Telemetry and satellite tracking of whale sharks, *Rhincodon typus*, in the Sea of Cortez, Mexico, and north Pacific Ocean. *Environ Biol Fish* 60:299–308
- Garrick JAF (1964) Additional information on the morphology of an embryo whale shark. *Proc U S Natl Mus* 115:10
- Graham R, Roberts CM (2007) Assessing the size, growth rate and structure of a seasonal population of whale sharks (*Rhincodon typus* Smith 1828) using conventional tagging and photo identification. *Fish Res* 84:71–80
- Hanfee F (1997) Trade in sharks and its products in India. TRAFFIC India, New Delhi
- Hanfee F (2001) Trade in whale shark and its products in the coastal state of Gujarat, India. TRAFFIC India, New Delhi
- Heyman W, Graham R, Kjerfve B, Johannes RE (2001) Whale sharks *Rhincodon typus* aggregate to feed on fish spawn in Belize. *Mar Ecol Prog Ser* 215:275–282
- Hoffmayer ER, Franks JS, Shelley JP (2005) Recent observations of the whale shark (*Rhincodon typus*) in the north-central Gulf of Mexico. *Gulf Caribb Res* 17:117–120
- Holland KN, Wetherbee BM, Peterson JD, Lowe CG (1993) Movements and distribution of hammerhead shark pups on their natal grounds. *Copeia* 495–502
- Hueter RE, Heupel MR, Heist EJ, Keeney DB (2004) Evidence of philopatry in sharks and implications for the management of shark fisheries. *E-J Northwest Atl Fish Sci* 35:7
- Hueter R, Gonzalez Cano J, Remolina Suarez F, de la Parra R, Tyminski J, Perez Ramirez J (2005) Whale shark summer feeding grounds where the Gulf of Mexico meets the Caribbean Sea. In: Joint meeting of Ichthyologists and Herpetologists, Tampa, pp 234–235
- Joung SJ, Chen C-T, Clark E, Uchida S, Huang WYP (1996) The whale shark, *Rhincodon typus*, is a live-bearer: 300 embryos found in one 'megamamma' supreme. *Environ Biol Fish* 46:219–223
- Kohler NE, Turner PA (2001) Shark tagging: a review of conventional methods and studies. *Environ Biol Fish* 60:191–223
- Krishna-Pillai S (1998) On a whale shark *Rhincodon typus* found accompanied by its young. *Mar Fish Inf Serv* 152:15
- Kukuyev EI (1995) The new finds in recently born individuals of the whale shark *Rhincodon typus* (Rhiniodontidae) in the Atlantic Ocean. *J Ichthyol* 36:203–205
- Martin AR (2007) A review of behavioural ecology of whale sharks (*Rhincodon typus*). *Fish Res* 84:10–16
- Meekan MG, Bradshaw CJA, Press M, McLean C, Richards A, Quasnichka S, Taylor JA (2006) Population size and structure of whale sharks (*Rhincodon typus*) at Ningaloo Reef, Western Australia. *Mar Ecol Prog Ser* 319:275–285
- Merson RR, Pratt HLJ (2001) Distribution, movements and growth of young sandbar sharks, *Carcharhinus plumbeus*, in the nursery grounds of Delaware Bay. *Environ Biol Fish* 61:13–24
- Nammalvar P (1986) Indian whale shark fishery. Marine Fisheries Information Service, Cochin
- Nishida K (2001) Whale shark—the worlds largest fish. In: Kakabo T, Machida Y, Yamaoka K, Nishida K (eds) *Fishes of the Kuroshio current, Japan*. Osaka Aquarium Kaiyukan, Minato-ku, Osaka, pp 20–35
- Pratt HLJ, Carrier JC (2001) A review of elasmobranch reproductive behavior with a case study on the nurse shark, *Ginglymostoma cirratum*. *Environ Biol Fish* 60:157–188
- Pravin P (2000) Whale shark in the Indian coast—need for conservation. *Curr Sci* 79:310–315
- Reid GK (1957) External morphology of an embryo whale shark, *Rhincodon typus*, Smith. *Copeia* 2:157–158
- Rowat D (1997) Seychelles whale shark tagging project—pilot project report. *Phelsuma* 5:77–80
- Rowat D (2007) Indian Ocean whale shark occurrence: a case for regional conservation. *Fish Res* 84:96–101
- Rowat D, Gore M (2007) Regional scale horizontal and local scale vertical movements of whale sharks in the Indian Ocean off Seychelles. *Fish Res* 84:32–40
- Rowat D, Meekan MG, Engelhardt U, Pardigon B, Vely M (2006) Aggregation of juvenile whale shark (*Rhincodon typus*) in the Gulf of Tadjoura, off Djibouti. *Environ Biol Fish* (in press) DOI 10.1007/s10641-006-9148-7
- Simpfendorfer CA, Milward NE (1993) Utilisation of a tropical bay as a nursery area by sharks of the families Carcharhinidae and Sphyrnidae. *Environ Biol Fish* 37:337–345
- Sims DW, Nash JP, Morritt D (2001) Movements and activity of male and female dogfish in a tidal sea lough: alternative behavioural strategies and apparent sexual segregation. *Mar Biol* 139:1165–1175
- Taylor G (1989) Whale sharks of Ningaloo Reef, Western Australia, a preliminary study. *West Aust Nat* 18:7–12
- Taylor G (1994) Whale sharks. Angus & Robertson, Sydney
- Wolfson FH (1983) Records of seven juveniles of the whale shark *Rhincodon typus*. *J Fish Biol* 22:647–655
- Wolfson FH (1986) Occurrences of whale shark *Rhincodon typus*, Smith. In: Uyeno T, Arai R, Taniuchi T, Matsuura K (eds) 2nd international conference on Indo Pacific fishes. Ichthyological Society of Japan, Tokyo, pp 208–226
- Wood GL (1990) *Animal facts and feats*. Stirling, New York