Marine Biology

DOI 10.1007/s00227-004-1518-0

Research Article

On the gestation period of the blackfin reef shark, *Carcharhinus melanopterus*, in waters off Moorea, French Polynesia

I. F. Porcher (✉)

I. F. Porcher
B.P. 4206, 98713 Papeete, Tahiti, French Polynesia

✉ I. F. Porcher
E-mail: ila@smartech.p

Received: 19 August 2004 / **Accepted:** 18 October 2004

Abstract Underwater visual and photographic observations, over a four year period, monitored the presence of mating wounds on female blackfin reef shark, *Carcharhinus melanopterus*. Mating begins in November and continues until the end of March as each female follows her own temporal cycle. Correspondingly, parturition begins in September and continues until January. Each female again mates 1.5–2.5 months after parturition, thus completing an annual reproductive cycle. The gestation period is 286–305 days, with slight individual differences. All resident sharks under observation followed this pattern. Evidence of reproductive events presented by transient females conformed with the pattern of the residents.

G.F. Humphrey, Sydney

Introduction

The few studies postulating a gestation period for the blackfin reef shark, *Carcharhinus melanopterus*, have varied greatly in their conclusions. Based on an examination of embryo development, Melouk (1957) claimed a 16-month gestation for the species. Based on measurements of embryos in pregnant females and supported by testes-mass to body-mass calculations, Stevens (1984) concluded that the gestation period was 10–11 months. Lyle (1987) examined the reproductive organs of blackfins caught in nets, and concluded that their gestation period was 8–9 months. Concluding that an entirely new method was needed to resolve these conflicting findings, I used direct observations of the sharks, and found values close to those proposed by Stevens (1984).

Mating wounds have been commonly found on females of many species of elasmobranchs (Kajiura et al. 1999; Pratt 1979; Jensen 2002). The male reportedly grasps the female by her pectoral fin with his mouth to stabilize the pair, while mating (Tricas and LeFeuvre 1985; Jensen 2002). These wounds infer mating activity in the observed females, and wounding can be extensive on the pectoral fins as well as along the posterior, lateral, dorsal or ventral body surfaces. Kajiura et al. (1999), wrote: “Fresh wounds are formed during periods of active courtship and copulation, and can thus serve as indicators of mating activity even when it is not directly observed.” Jensen also noted that fresh bites observed on a female shark “ ...may coincide with insemination and ovulation, marking the approximate beginning of the gestation period.”

The pregnancy of each resident shark was monitored. Parturition was signalled by the reappearance of the newly slender female.

Materials and methods

The concept that individuals can be distinguished by their appearance underlies photo-identification techniques. These have become standard practice in the study of marine mammals (Hammond 1986; Defran et al. 1990; Würsig and Jefferson 1990) and have been used effectively on white sharks, *Carcharodon carcharias* (Anderson and Goldman 1997). Working underwater, I complemented photo-identification techniques by accurately drawing both sides of the dorsal fin and recording the length, color, gender, behaviour, scars, marks, and more subtle distinguishing features of each shark ranging the western part of the Vaihapu region (Galzin and Pointer 1985) off Moorea Island. The appearance of each individual on both sides was recorded to avoid error in future sightings wherein only one side might be visible. On encounters, sharks have a tendency to fix one eye on the observer, resulting in circling. Efforts to see the shark’s other side are countered by the shark, who appears reluctant to lose this visual contact. The drawings, with written descriptions, served as well as photographs, and resulted in the identification of over 450 individuals.

Observations over a period of 4 years were carried out 2–3 times weekly, conditions permitting, and more often when events demanded it. Presence, condition, and signs of reproduction were recorded for each individual. The residents were identified and became familiar to me during the first 3 months; the total number of adult females observed was 172.

Results

Structure of wounds

Mating wounds in *C. melanopterus* consisted mostly of punctures and cuts of about 2–3 cm in length. A few were much longer and gaped open, revealing the subdermal layer. They appeared as sets of parallel and single cuts, angling posteriorly, in which no flesh was removed, and apparently inflicted by the upper jaw of the male during mating (Pratt 1979). One or both pectoral fins were usually sliced, sometimes to the leading edge, in several places (Tricas and Le Feuvre 1985; Jensen et al. 2002). Dermal tissue was removed between bite-marks wherever they were close together. The deepest, gaping cuts occurred below the lower colour-line (Figs. 1, 2) where the skin might be easier to pierce and slice. These wounds typically covered the females with a fine latticework in a long teardrop shape on each side, beginning in front of the gills, widening to the dorsal fin, extending below the lower colour-line, and tapering off, at or before the second dorsal fin. When fresh, the wounds looked clear-cut, and light-red, vascularised tissue was visible. Then the edges softened and the wounds paled. Within 4 or 5 days, the cuts were edged in black and began to close. Klimley and Nelson (1981) also reported that abrasions on female scalloped hammerhead sharks, *Sphyrna lewini*, became black patches during healing. The shallower bites healed and disappeared in 10 days, leaving a wider spaced network of black lines. Only the deepest cuts still gaped. The pectoral fins were almost healed in 10 days with one or two wounds still presenting an open V-shape less than 2 cm long on their trailing edges. These had closed 2–3 weeks after mating. The mating wounds had completely healed in 4–6 weeks; the gaping wounds below the colour-line remained visible longest, as dark lines. The skin was left mottled with paler marks which slowly normalized during the following weeks. For about 2 months, the shark's overall colour was paler than normal.

Fig. 1 Illustration of the appearance of obesity in pregnant resident blackfin reef shark, *Carcharhinus melanopterus*, no. 3

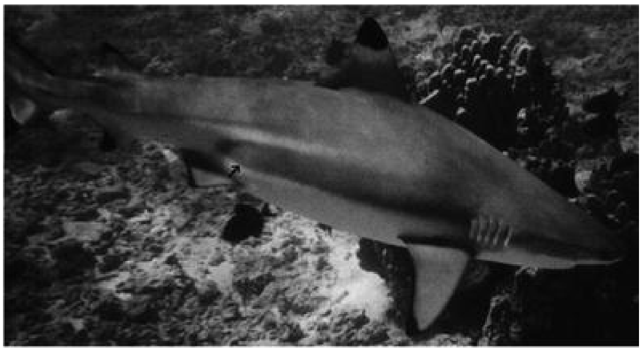

Fig. 2 Illustration showing the prominent bulging of the body wall anterior to the pelvic fins a few days before parturition

Occasionally, a female showed cuts in only a few places. Appearing in parallel lines, these again suggested bites from the upper jaw of the male (Pratt 1979). Such cuts were usually on the dorsal surface or flanks, posterior to the first dorsal fin. However, the full set of lacerations as described above occurred only once per season per individual.

Females appeared with mating wounds one by one throughout the warm season, from November to March. The sole exception was an individual that mated within the first 3 days of April in one year. No similar bites were seen on males, though rarely one appeared with a bite-mark. Occasionally, a male presented a slash-wound, usually vertical on his side near the gills, from near the dorsal ridge to the curve of the ventral surface.

Temporal cycle

The progression of pregnancy was followed after noting mating by an individual. Soon the streamlined shape, typical of the non-pregnant female, became more rounded as her circumference increased. By contrast, males have a less convex profile. Clear, abdominal distension became apparent after 3 or 4 months and was never noted in non-pregnant females; these always maintained a sleek outline. As months passed, both the abdominal swelling and obese appearance, became more prominent (Fig. 1). The slight angle on the dorsal surface, posterior to the head, became more acute. About 2 weeks before parturition, the lower abdomen near the pelvic fins, began to bulge on each side (Fig. 2), so that viewed from behind, this area acquired a squared shape. When parturition approached, distension there became extreme, creating a gap between the pelvic fins and the body about 3 cm wide at the fins' tips, presumably due to the young moving into position for parturition. Parturition resulted in a remarkable change in the shark's appearance. She reappeared in her home range looking almost emaciated (Fig. 3), and some individuals, though not all, became strikingly paler. Over the following few weeks, her usual colour and more convex profile were re-established.

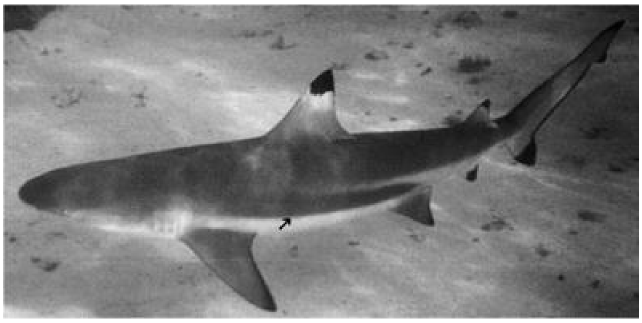

Fig. 3 Individual no. 3 (Fig. 1) after parturition

Parturition began in September after about 10 months (Fig. 4). Each individual mated again after a period of about 40–90 days although the usual resting period was 45–75 days. Young females appeared to be more erratic in the timing of their cycle from year to year, but the older individuals tended to mate and give birth at approximately the same time, often to the week, year after year. Each shark reproduced annually, as noted by Lyle (1987). Of 13 monitored young female sharks mating for the first time, only 2 became pregnant, while fully mature sharks almost never failed to reproduce successfully each year. The evidence of reproductive events obtained on transient females agreed with observations of the residents.

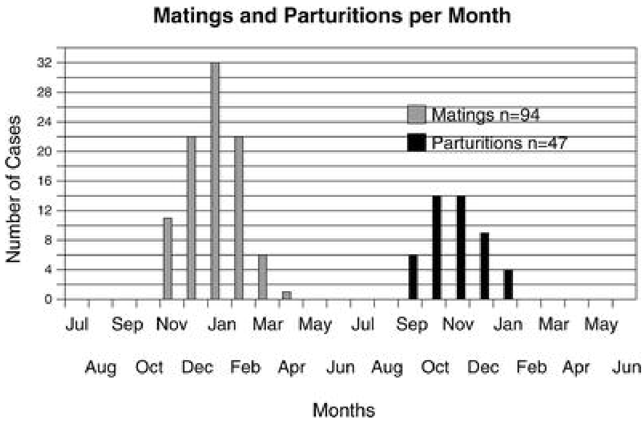

Fig. 4 Reproductive events by month. Each *column* is the sum of the events seen in that month over the 4-year period. Parturition-data are fewer than mating-data due to the tendency of females to roam extensively before and after the former event

The upper and lower limits of sample gestation periods in cases where the shark was observed regularly throughout her pregnancy are presented in Fig. 5. These were residents with little tendency to roam, so some could be watched year after year. Other residents left their home ranges for such long periods during the reproductive season that the timing of either mating or parturition could not be accurately determined.

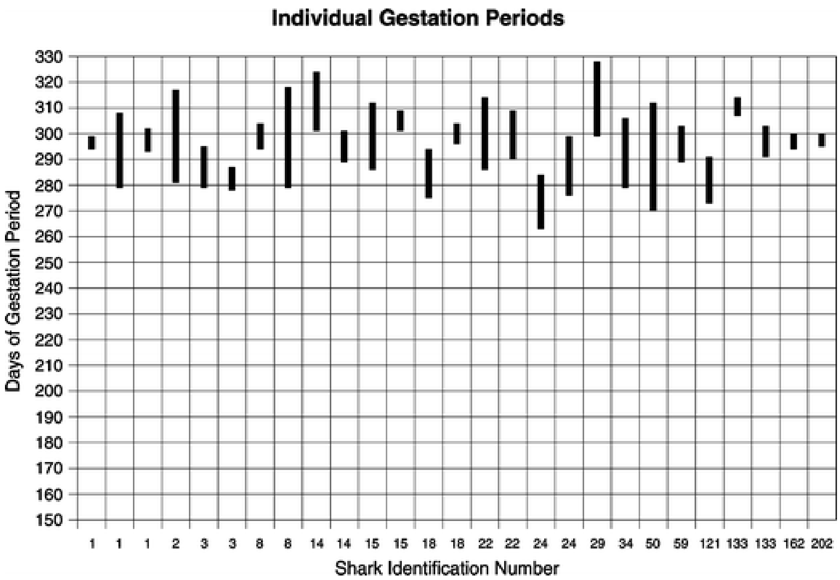

Fig. 5 Sample gestation periods by residents. Certain individuals were monitored year after year, permitting comparison of successive gestation periods. The minimum figure gives the number of days from the first sighting of the shark after mating to the last one before parturition. The maximum figure gives the number of days from the last sighting before mating to the first after parturition. *n*=27. Averages: minimum: 286.6±10.7 days; maximum: 305.1±10.5 days

The shallow regions at both ends of the barrier reef bordering the Vaihapu area were used as pupping grounds. Neonates appeared there in general correlation with the timing of noted parturitions, serving as confirming evidence of this facet of the reproductive cycle.

Discussion

While a camera or video-camera only records the scene-data frame by frame, the human eye can instantly capture and integrate needed information as it follows the moving image of the shark. By simultaneously recording this information through drawing on a slate, a cognitive process involving visual information extraction, normalisation, and solidification is completed, that no machine is yet able to do.

In the time it takes to raise a camera and frame a swiftly passing shark, the animal may well have proceeded so far that the dorsal fin pattern is no longer visible. There is the possibility that the sudden movement will cause the shark to veer. Often a shark is too far away to capture on film, though the pattern of its dorsal fin is clearly seen. Drawing can extract information from swiftly moving sharks in low light conditions, which are unsuitable for photography. Further, the drawing process etches the appearance of the shark on the mind, facilitating future recognition. Therefore, with my technique, many times the amount of information was obtained, per unit of time, than would have been possible with photo-identification techniques alone.

My results indicate a gestation period of between 286 and 305 days, with minor individual differences, and an annual reproductive cycle for *Carcharhinus melanopterus* off Moorea Island, which is in the southern hemisphere. Melouk (1957), in his study of embryonic development in this species, found that the reproductive season in the Red Sea, in the northern hemisphere, also takes place during the warm months. His assumption of a 16-month gestation period was given in the introduction of his paper, but was not substantiated with data to permit the reader to follow his reasoning. It was based on the finding of "...embryos about 2 cm long as well as advanced stages about 40 cm long..." in different individuals in May, then, " ...older stages measuring about 3 to 4 cm as well as foeti (sic) about 50 cm long..." in June. No data exist for July and only an expectation is offered for August, when neonates were found " ...commonly round the shores." Given that he infers that parturition occurs in August, a 16-month gestation period means that mating occurred in May of the previous year. However, according to his own data, the embryos were already 2 cm long in May. This contradiction is not addressed nor does he mention how long it takes for an embryo to grow to a length of 2 cm, a point mid-way between the stages 6 and 7 described in his paper, when the embryo is already well developed. He states that " ...mating season starts, as far as it could be ascertained, early in summer...", but he does not specify the method used to ascertain the start of mating nor when, precisely, early summer occurs in the Red Sea. Since fetuses of 50 or even 40 cm in length, should be close to parturition, one wonders whether parturition might begin earlier than August. This point is not mentioned, nor are sample sizes. The few data in Melouk (1957) are not inconsistent with my observations that some sharks had already undergone parturition and mated again, while others had not. However, his data are inadequate to determine the gestation period.

Stevens (1984) made an extensive tagging study of the sharks at Aldabra Atoll in the Indian Ocean and dissected a number of individual *C. melanopterus* to determine their reproductive cycle. He postulated a gestation period of 10–11 months for this species with mating occurring in October and November, and parturition in October, based on measurements of embryos in pregnant females and supported by testes-mass to body-mass calculations. His study suggests that the mating season at Aldabra is restricted to October and November and he found that about half the females became pregnant each year and were in a resting period during the following year. The intense intraspecific and interspecific competition for food, he reported, could be a factor in the alternate-year reproductive cycle occurring there and his results indicate a distinct variation in the reproductive cycle of *C. melanopterus* between these two distant island groups, Aldabra Atoll in the Indian Ocean, and French Polynesia in the mid South Pacific Ocean.

Lyle (1987) postulated an 8- or 9-month gestation period, following examination of the reproductive organs of sharks caught in nets in northern Australia. His data indicate a mating season underway in November to March and trailing off in April. These data correlate with mine. He mentions two individuals with low ovary weights and low ova diameters in February, explaining that the gonads appeared to be in a resting state: " ...uteri were expanded but ova were small and without yellow yolk typical of the pre-ovulatory condition." This state could have been found in individuals that had undergone parturition and were not ready to mate again, typical of some individuals at this time of year off Moorea. Lyle (1987) mentions a female with uterine eggs in March, indicating that ovulation extended into that month as well. This is also consistent with my findings. Lyle's conclusion of a relatively short gestation period might have been affected by small sample sizes. He states, "The paucity of material in November-December and the absence of females with mating scars make it difficult to establish the precise timing of the mating season." Insufficient data (only one female and no males during the important month of December) might have led to an incorrect conclusion, particularly given the variation I observed in the timing of the reproductive cycles of different individuals.

Johnson (1978a, 1978b) stated that two mating seasons had been reported in the Indian Ocean for *C. melanopterus*: June to July and December to January. He added that in French Polynesia, evidence supports this dual pattern. Since he did not specify what this evidence was, it is not possible to discuss it here, and apparently Johnson did not determine the reproductive cycle in detail. Since the reproductive pattern I observed was clear and precisely repeated year after year, I conclude that there is no biannual reproductive cycle in French Polynesia. A biannual cycle observed in the Indian Ocean might be related to the proximity of the equator, where the warm season might be less distinct. Depending on movement patterns of the species, regions from both hemispheres could have been the origins of the sharks within the given population, each individual continuing its ancestral cycle in the present-time. Further observations and DNA studies could help reveal such possible influences on variations in the reproductive patterns of this species in different regions.

Acknowledgments I sincerely thank A.A. Myrberg, Jr. for his encouragement, for locating needed references, and reviewing and advising me on the manuscript. Thanks to J. Castro, R. Galzin, L. Paul, and M. Kazmers for providing references. My husband, F. Porcher, reviewed and provided helpful suggestions on the manuscript. The Centre de Recherches Insulaires et l'Observatoire de l'Environnement, on Moorea, and the Richard Gump South Pacific Research Station, University of California at Berkeley, on Moorea, permitted me access to their libraries. All observations comply with the laws of French Polynesia.

References

Anderson S, Goldman K (1997) Photographic identification of white sharks, *Carcharodon carcharias*, at the South Farallon Islands, central California. American Elasmobranch Society 1997 Annual Meeting, Seattle, Washington

Defran RH, Schultz GM, Weller DW (1990) A technique for the photographic identification and cataloguing of dorsal fins of the bottlenose dolphin (*Tursiops truncatus*). Rep Int Whal Comm. Spec Issue 12:53–55

Galzin R, Pointer JP (1985) Moorea Island, Society Archipelago. In: Delesalle B, Galzin R, Salvat B (eds) French Polynesian Coral Reefs, vol 1. 5th International Coral Reef Congress, Tahiti, 27 May to 1 June 1985, pp 73–102

Hammond PS (1986) Estimating the size of naturally marked whale populations using capture-recapture techniques. Rep Int Whal Comm Spec Issue 8:253–282

Jensen CF, Natanson LJ, Pratt HL Jr, Kohler NE, Campana SE (2002) The reproductive biology of the porbeagle shark (*Lamna nasus*), in the Western North Atlantic Ocean. Fish Bull 100:727–738

Johnson RH (1978a) Sharks of Polynesia. Les Editions du Pacifique, Singapore

Johnson RH (1978b) Sharks of tropical and temperate seas. Les Editions du Pacifique, Papeete, Tahiti, French Polynesia

Kajiura SM, Sebastian AP, Tricas TC (1999) Dermal bite wounds as indicators of reproductive seasonality and behavior in the Atlantic stingray, *Dasyatis sabina*. Environ Biol Fish 58:23–31

Klimley AP, DR Nelson (1981) Schooling of the scalloped hammerhead shark, *Sphyrna lewini*, in the Gulf of California. US Fish Bull 79:356–360

Lyle JM (1987) Observations on the Biology of *Carcharhinus cautus* (Whitley), *C. melanopterus* (Quoy & Gainard) and *C. fitzroyensis* (Whitley) from Northern Australia. Aust. J Mar Fr Res 38:701–10

Melouk MA (1957) On the Development of *Carcharhinus Melanopterus* [sic] (Q. & G.). Mar Biol Station, Ghardaqa (Red Sea), no. 9:229–251

Pratt HL Jr (1979) Reproduction in the blue shark, *Prionace glauca.* US Fish Bul. 77:445–470

Stevens JD (1984) Life-history and ecology of sharks at Aldabra Atoll, Indian Ocean. Proc R Soc Lond B 222:79–106

Tricas TC, LeFeuvre FM (1985) Mating in the reef white-tip shark *Triaenodon obesus*. Mar Biol 84:233–237

Würsig B, Jefferson TA (1990) Methods of photo-identification for small cetaceans. Rep Int Whal Comm Spec Issue 12:43–50