Shark predation on Indian Ocean bottlenose dolphins *Tursiops truncatus* off Natal, South Africa

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The incidence of shark induced scars on Indian Ocean bottlenose dolphins caught in gill nets off Natal, on the south-east coast of southern Africa, was monitored between January 1983 and June 1987. The occurrence of dolphin remains in sharks caught in these nets between January 1980 and December 1985 was also recorded. Of the dolphins caught, 10,3% exhibited scars or wounds consistent with shark bites. Only 1,2% of over 6000 sharks caught contained cetacean remains. Four species of shark, the Zambesi *(Carcharhinus leucas)*, the tiger *(Galeocerdo cuvieri)*, the great white *(Carcharodon carcharias)* and the dusky shark *(Carcharhinus obscurus)* were implicated as dolphin predators. Estimates from the number of these four species caught annually and the frequency of occurrence of dolphin flukes and vertebrae in their stomachs suggest that a mininum of 20 bottlenose dolphins or 2,2% of the estimated population in southern Natal coastal waters are killed each year by sharks.

Die voorkoms van littekens veroorsaak deur haaie op Indiese Oseaan-stompneusdolfyne wat gevang is in kiefnette in Natal, aan die suidoos kus van suidelike Afrika, is tussen Januarie 1983 en Junie 1987 aangeteken. Die voorkoms van dolfynoorblyfsels in haaie gevang in hierdie nette tussen Januarie 1980 en Desember 1985 is ook aangeteken. Van die dolfyne wat gevang is het 10,3% littekens of wonde vertoon wat ooreenstem met haaibyte. Slegs 1,2% van oor die 6000 haaie wat gevang is het oorblyfsels van Cetacea bevat. Vier spesies van haaie, die bulhaai *(Carcharhinus leucas)*, die tierhaai *(Galeocerdo cuvier)*, die witdoodshaai *(Carcharodon carcharias)* en die donkerhaai *(Carcharhinus obscurus)* is aangedui as roofdiere van dolfyne. Skattings van die getalle van die vier spesies wat jaarliks gevang word en die frekwensie van aanwesigheid van dolfynvinne en rugwerwels in die mae dui daarop dat 'n minimum van 20 stompneusdolfyne of 2,2% van die geskatte bevolking in suidelike Natalse kuswaters jaarliks deur haaie doodgemaak word.

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An assessment of the extent, causes and sources of natural mortality in marine mammal populations presents some formidable problems (Gaskin 1982). One source of natural mortality is that from predation by killer whales and sharks. Shark predation on seals is well documented and mortality resulting from this source may be significant in the population dynamics of certain seal populations such as the Hawaiian monk seal (Kenyon 1981) and the grey seal in eastern Canada (Brodie & Beck 1983). Furthermore, Ainley, Henderson, Huber, Boekelheide, Allen & McElroy (1985) propose that the abnormal timing of the breeding season of the northern elephant seal on the Farallon Islands may, in part, be a response to white shark predation pressure on newly weaned pups. They further speculate that the timing of breeding seasons of other seals may be, partially, an evolutionary response to shark predation.

Although the predatory interactions between sharks and cetaceans have been observed or inferred on numerous occasions (Wood, Caldwell & Caldwell 1970; Ross & Bass 1971; Leatherwood, Perrin, Garvie & LaGrange 1972; Arnold 1972; Ross 1977; Saayman & Tayler 1979; Norris & Dohl 1980; Stevens 1984; Corkeron, Morris & Bryden 1987), little is known concerning the frequency of shark attack on cetaceans or their influence on dolphin populations. Norris & Dohl (1980) reported that spinner dolphins off Hawaii were apparently attacked with some frequency. Corkeron *et al.* (1987) found that 36,6% of identified bottlenose dolphins in Moreton Bay, Queensland, Australia showed definite evidence of shark attack. In South African waters, Ross (1977) noted that although the level of shark predation on bottlenose dolphins was unknown it appeared to be low based on the number of animals displaying shark bite scars.

On the Natal coast (Figure 1) 44 prime bathing beaches are protected by inshore gill nets, set to catch and reduce the number of sharks off these beaches. Currently, some 1400 sharks are caught in these nets annually. In addition, three species of dolphin, the Indian Ocean bottlenose dolphin *Tursiops truncatus*, the Indo-Pacific humpback dolphin *Sousa plumbea* and the common dolphin *Delphinus delphis*, are captured and killed incidentally in these nets. Common dolphins frequent Natal only during mid-winter, from June to September, when they migrate northwards in association with a winter migration of pilchards *Sardinops ocellatus*. In contrast, humpback and bottlenose dolphins occur in the Natal inshore region throughout the year and there is concern that the continued mortality of these species in the nets may deplete their respective Natal populations.

Access to both net-captured dolphins and sharks provided a unique opportunity to gain an insight into shark predation on bottlenose dolphins. The incidence of shark attack on humpback dolphins is reported elsewhere (Cockcroft, in press).

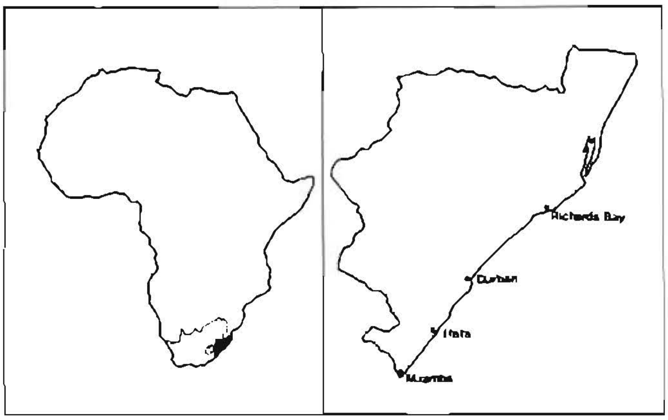

Figure 1 Natal, on the east coast of southern Africa between 27°S and 31°S. Gill nets to catch sharks are set at 44 prime bathing beaches between Richards Bay and Mzamba.

Materials and Methods

Over the period January 1980 to December 1985, 6878 sharks of 16 species were necropsied. During these necropsies the contents of the stomachs were removed and washed. Vertebrate remains other than fishes were closely examined. Amongst these remains, ingested flippers, flukes and vertebrae were relatively easily identified. Blubber was also easily identifiable, and classified as whale or dolphin blubber on its thickness, that of dolphins being thin in comparison to that of whales. Certain skeletal material and muscle were often not identifiable with any certainty, and were excluded for the purposes of this study.

Bottlenose dolphins caught between January 1983 and June 1987 were inspected, during routine dissections, for the presence of old scars or recent wounds. The decomposed condition of some dolphins made it difficult to determine the presence of scars and, owing to time constraints, not all animals were examined with equal effort. Only scars or fresh wounds forming single or double arcs on the body, similar to type 1, 2 and 5 injuries observed on penguins by Randall, Randall & Compagno (1988), were classed as shark bites and were included in this study. The number and position of scars or recent wounds was noted and photographs taken. Measurements were taken across the axes of recent wounds. Fresh wounds obviously inflicted subsequent to capture in the nets were excluded.

Results

Twenty-eight of the 145 bottlenose dolphins captured showed scars or wounds that may have resulted from shark attack. Of these only 15 exhibited single or multiple scars or wounds that fulfilled the criteria set for shark bite (Table 1). Recent bite wounds (Figure 2) were observed in June and July only, in four different years. The widths of all four recent bites were measured (20 cm, 23 cm, 25 cm and 35 cm). The identity of the shark or sharks responsible for any of the scars or recent wounds was not established.

Only two of the 15 dolphins were calves less than 200 cm in length while all others were subadults or adults greater than 220 cm in length. Only three (20%) of the 15 were caught north of Durban (north coast), two (13%) between Ifafa and Durban (upper south coast) and the remainder (67%) between Mzamba and Ifafa (lower south coast). The majority of bite scars were posteriorly situated and generally on the ventral, paler portions of the body, slightly anterodorsal to the genital area.

Ten (7%) of the 145 bottlenose dolphins caught showed signs of having been scavenged in the nets subsequent to capture. The most commonly scavenged areas of the body were the soft underbelly and posterior flanks. In only one instance were the flippers removed but in no instances were the flukes or any vertebrae removed. Consequently, the presence of flukes or vertebrae in shark stomachs was considered a more reliable indicator of dolphin mortality owing to predation than the presence of blubber or unidentified small cetacean (dolphin) pieces.

Only 89 sharks (1,2%), covering nine species, contained dolphin remains. In only three shark species, the Zambesi *Carcharhinus leucas*, the tiger *Galeocerdo cuvieri* and the great white *Carcharodon carcharias*, was the frequency of dolphin remains in stomachs more than

Table 1 The number of bottlenose dolphins showing evidence of shark bite caught in the Natal shark nets between January 1983 and June 1987

	No.	%
Single scars	4	2,8
Multiple scars	7	4,8
Recent wounds	4	2,8
Total	15	10,3
Total No. of dolphins examined	145	

Figure 2 PEM N1058, an adult female *Tursiops truncatus* showing a 21 cm × 35 cm semi-healed shark bite probably inflicted sometime in June or July 1984.

Table 2 The percentage frequency of occurrence of flukes and vertebrae in great white sharks >180 cm SL, dusky sharks >170 cm SL, tiger sharks >190 cm SL and Zambesi sharks >140 cm SL, caught between November and May

	Great white	Dusky	Tiger	Zambesi
Frequency of occurrence (%), between November and May, of flukes and vertebrae in shark stomachs	1	0,2	1,9	2,2

Figure 3 The remains of a young dolphin found in the stomach of a 290 cm, female great white shark caught in the Natal shark nets.

1% (Table 2). Additionally, the remains of dolphin flukes and vertebrae occur only in these three species and the dusky shark *Carcharhinus obscurus* (Table 2).

Notes kept on flukes and vertebrae recovered from the stomachs of sharks showed that remains were unidentifiable to species but indicated that the majority were from young dolphins (Figure 3). This was determined by the relative size of the flukes and the degree of fusion of the epiphyses to the centra of vertebrae. Unfortunately, most of this material was discarded and further assessment of age was not possible.

The total lengths of Zambesi, tiger, great white and dusky sharks capable of delivering the smallest and largest of the recent wounds were calculated using figures given by Bass, D'Aubrey & Kistnasamy (1973, 1975a, 1975b) (jaw width 11,5%, 9%, 7,8% and 10% of total length, respectively) (Table 3). The percentage of total catch of each species larger than that predicted by the smallest bite width is also shown. Catches of these four shark species containing dolphin remains occurred throughout the year, although catches in June, July and November were marginally greater (Figure 4).

Five sharks were caught together with bottlenose dolphins. In only one instance did the shark contain cetacean remains suggesting it had been scavenging. The majority (42%) of sharks containing small cetacean

Table 3 Estimated total lengths (TL) and standard lengths (SL) of four species of shark inflicting 20 cm and 35 cm width bites on bottlenose dolphins. The percentage catch of these sharks estimated to have a bite width exceeding 20 cm is also given, (TL to SL conversions after Bass *et al.* 1973, 1975a, 1975b)

	Estimated length from bite width				
	20 cm		30 cm		% of catch
	TL	SL	TL	SL	> col. 1
Carcharhinus leucas	180	140	304	236	89,5
Galeocerdo cuvieri	260	190	470	343	43,9
Carcharodon carcharias	220	180	390	320	88,5
Carcharhinus obscurus	200	170	350	280	49,2

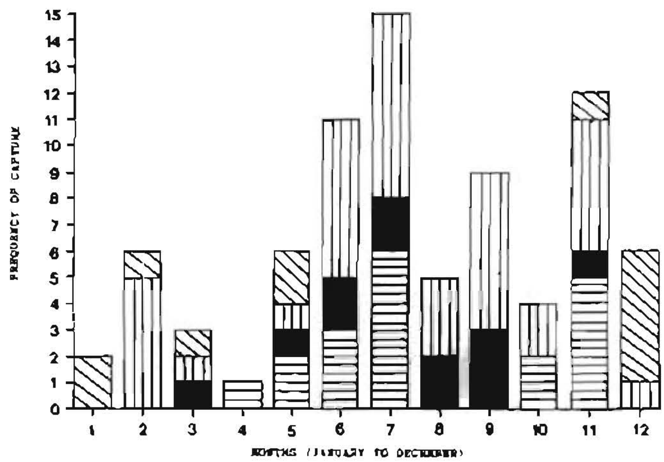

Figure 4 The monthly frequency of capture of great white (horizontal bars), tiger (vertical bars), dusky (solid black) and Zambesi (inclined bars) sharks over the period January 1980 through December 1985.

remains were caught south of Ifafa (lower south coast); 32% and 26% were caught between Ifafa and Amanzimtoti (upper south coast) and between Durban and Richards Bay (north coast), respectively. Varying proportions of sharks captured had everted stomachs and therefore no stomach remains. The percentage of examined Zambesi, great white, dusky and tiger sharks with everted stomachs was 2,7%, 11,6%, 1,5% and 13,2% respectively.

Discussion

There is circumstantial evidence that Natal bottlenose dolphins actively avoid encounters with large sharks. They consistently avoid dirty, discoloured water (Ross 1977). This behaviour may be an attempt to minimize confrontations with some species of big sharks, large numbers of which have been seen just inside and on the borders of discoloured water (pers. obs. VGC and GJBR) during aerial surveys conducted along the Natal coast. Most shark attacks on humans, on the Natal coast, also occur when the water is turbid (Wallett 1973). There is also evidence that Natal bottlenose dolphins move offshore in the evening and only return to nearshore waters at first light (N.S.B. personnel, pers. comm. and Cockcroft, unpubl. data). This movement may be evidence of a diurnal rhythm (Klinowska 1986) in response to the inshore movement of some species of shark at dusk, apparently to feed overnight (Wallett 1973).

This study provides evidence that a minimum of 10,3% of bottlenose dolphins captured in Natal showed some sign of shark attack, although this may be an underestimate of shark – bottlenose dolphin interaction in this area. In Moreton Bay, Queensland, Australia, Corkeron *et al.* (1987) found 36,6% of bottlenose dolphins showed signs of attack by sharks, particularly great white and tiger sharks. The discrepancy between the former and latter estimates may result from the biased sex and size composition of the net sample (Cockcroft & Ross in press b). As both studies deal with dolphins surviving shark attack, it is impossible to relate the incidence of scars and wounds on surviving dolphins to the extent of attack or resulting mortality.

Nevertheless, the presence of shark-induced scars and wounds on dolphins in relation to other data provides some interesting information.

Multiple scarring on dolphins suggests that shark attack is relatively common, although often unsuccessful. The position of most scars and wounds observed in this study suggests that most attacks are aimed at the posterior, ventral surface of dolphins. This is in agreement with other studies on porpoises and seals which have suggested that attacks almost invariably occur from the rear and below (Arnold 1972; Tricas & McCosker 1984; McCosker 1985; Ainley *et al.* 1985).

The low number of calves and juveniles (< 200 cm in length) with bite scars is interesting considering that this size group constitute over 40% of the annual bottlenose dolphin catch (Cockcroft & Ross in press b). This disparity suggests that either calves and juveniles may not be attacked, that they are protected from attack by their mothers, or that attacks on young dolphins may almost always prove fatal. Corkeron *et al.* (1987) found that a large proportion of nursing female bottlenose dolphins in Moreton Bay displayed fresh bites and that mothers with calves showed shark avoidance behaviour, suggesting that females and their calves may be more prone to attack. The predominance of young dolphin remains found in the stomachs of sharks in Natal, supports this view and suggests that young animals may be particularly vulnerable to attack.

It is difficult to determine whether sharks contained small cetacean remains as a result of predation or scavenging. It is also uncertain whether dolphin capture in the nets occurs during avoidance of shark attack, scavenging occurring subsequent to this. However, the low association between scavenged netted dolphins and sharks containing dolphin remains and the small numbers of sharks and dolphins caught together suggest that captures of both occurred independently and that dolphin captures were not a result of harassment by sharks.

Four shark species are apparently involved in predation on dolphins off Natal – the Zambesi *Carcharhinus leucas*, the tiger *Galeocerdo cuvieri*, the great white *Carcharodon carcharias* and the dusky *Carcharhinus obscurus* – all of which have previously been implicated in marine mammal predation (Wood *et al.* 1970; Compagno 1984; McCosker 1985; Stewart & Yochem 1985; Alcorn & Kam 1986; Corkeron *et al.* 1987). A minimum dolphin mortality can be estimated from the frequency of occurrence of flukes and vertebrae in the stomachs of these four shark species, assuming, as seems justifiable from the scavenging data, that the presence of either of these represents one dolphin killed. Further, bottlenose dolphin mortality can be estimated if mortality of other dolphin species can be excluded. Thus, if sharks smaller than those indicated by the smallest bite (Table 3), those caught at Richards Bay, where the majority of humpback dolphin catches occur (Cockcroft, unpubl. data), and those captured during the Natal sardine run (June to October), during which common dolphins are present in Natal, are excluded, an estimate of bottlenose dolphin mortality can be derived.

The annual catch of the four shark species, with the above exclusions, is about 327 animals (Cliff, unpubl. data) and nearly 0,7% (2,3 sharks per annum) of these contained either dolphin flukes or vertebrae. Carey, Kanwisher, Brazier, Gabrielson, Casey & Pratt (1982) have suggested that large great white sharks may only need to feed once in six weeks, assuming they fill their stomachs at each feed. Although an assumption of equal metabolic and feeding rates for the other large sharks is speculative, these data suggest a predation mortality of some 20 bottlenose dolphins annually.

This figure is a gross estimate and includes a number of sources of error. Shark abundance is greater in June and July (Wallett 1978) and the presence of fresh wounds during these months only, suggests that predation on dolphins may be greater during this period. Sharks with everted or empty stomachs were included in calculations and would tend to reduce mortality estimates. Other shark species probably capable of killing a dolphin calf, have been ignored. In combination, the above factors suggest that a mortality of 20 bottlenose dolphins annually is a minimum estimate. However, the estimate is directly related to the assumed feeding and metabolic rates of sharks and would vary considerably according to these parameters.

Ross, Cockcroft & Melton (1987) have estimated the Natal population of bottlenose dolphins to approximate 900 animals. Although the derived estimate of annual bottlenose dolphin mortality can not be related to overall annual mortality as the population levels of sharks off Natal are unknown, it represents some 2,2% of the population estimate and is approximately half the mortality owing to net captures (Cockcroft & Ross in press b). This suggests that predation by sharks may account for significant numbers of bottlenose dolphins and possibly other inshore dolphins.

Bottlenose dolphins are likely to have adapted both behaviourally and physiologically to this predation pressure to minimize its effect on the population. The avoidance of turbid water and the efficient camouflaging of the young calf (Cockcroft & Ross in press, a) are possible examples of these adaptations.

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