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LETHAL TIGER SHARK (*GALEOCERDO CUVIER*) ATTACK ON BOTTLENOSE DOLPHIN (*TURSIOPS* SP.) CALF: DEFENSE AND REACTIONS BY THE MOTHER

Tiger sharks (*Galeocerdo cuvier)* are known to prey on bottlenose dolphins (*Tursiops* sp.) (Bass *et al.* 1975, Corkeron *et al.* 1987, Cockcroft *et al.* 1989, Simpfendorfer 1992), but no attacks have been directly observed. The few observed shark attacks on delphinids involved mostly injured or dead individuals (*e.g.*, Wood *et al.* 1970, Ross and Bass 1971, Leatherwood *et al.* 1972). We document here an unusual event involving a lethal attack by a tiger shark on a bottlenose dolphin calf and subsequent defense of the calf carcass by the mother. The mother-calf pair was part of a longitudinal study; thus, we present systematic observational data on maternal behavior and associates in the weeks before and following the attack.

Between 1530 and 1535 on 19 March 1994, Hobbit, a 110-d-old dolphin was attacked by a shark near the Monkey Mia (a fishing camp/resort) shoreline in Shark Bay, Western Australia. Hobbit (Hbt) was the daughter of Holeyfin (Hol), one of the provisioned females who visited the shores daily for fish hand-outs and contact with fishers and tourists (for details about study site, see Connor and Smolker 1985, Smolker *et al.* 1992, Mann and Smuts 1998).

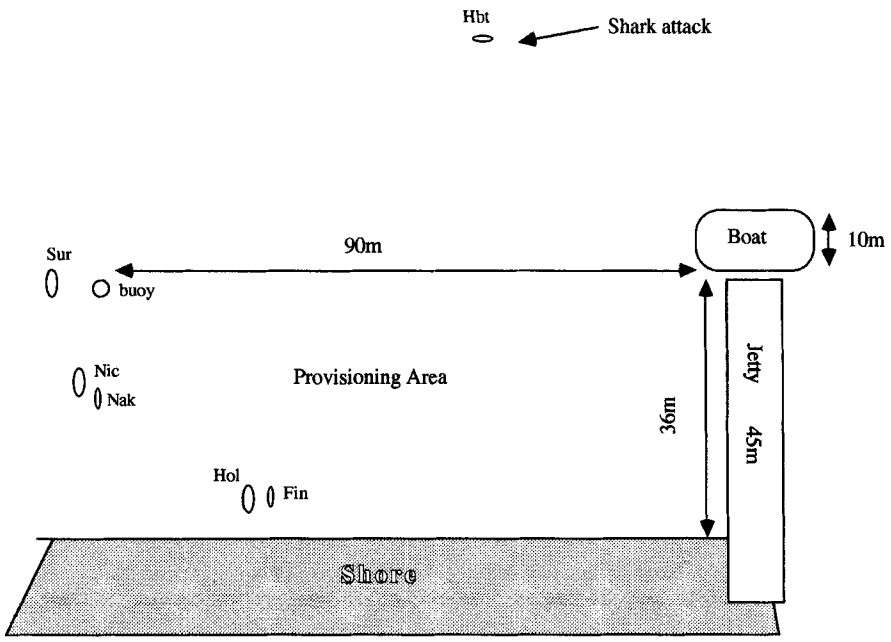

Figure 1. Diagram of provisioning area at Monkey Mia and where shark attack occurred. Ovals indicate placement of dolphins during attack. Not drawn to scale.

At least a dozen people witnessed the initial attack, which occurred approximately 70 m from shore in 5 m of water. Five witnesses, chosen because of their ability to identify all of the dolphins that visit the beach, (one tour operator, two resort employees, and two tourists) were interviewed independently within one day of the event. From 1550 to 1707, we observed Hol and Hbt's floating carcass from a 4-m dinghy. At 1707 we retrieved the carcass for necropsy.

Six dolphins were near the provisioning area when the attack occurred: Hol, Hbt, Sur (adult female), Nic (adult daughter of Hol), Nak (108-d-old son of Nic), and Fin (47-mo-old son of Nic). All five eyewitnesses agreed on the approximate location of the attack and the locations of Fin and Sur when the attack occurred. Two witnesses could identify where Nic, Nak, and Hol were at the time the attack started. The three other witnesses could remember only that Nic and Hol were near the beach and that either Nic or Hol were next to Fin. None of the witnesses provided contradictory information or conferred prior to being interviewed. Based on their accounts, the location of each dolphin at the time of the attack was reconstructed (Fig. 1). One witness (who could not be located for an interview) reported to the rangers that she was swimming just beyond the buoy when she watched a large shark swim within a few meters of her two children just prior to the attack.

At about 1535, Hol sped from the beach towards Hbt. Sur, Nic, and Fin followed seconds afterwards. All five witnesses agreed that the dolphins bolted

rapidly towards Hbt. Two observers were sure that Nak, the calf, stayed close to shore. Hol was estimated to have been at least 70 m from Hbt when the attack began. No one saw blood or evidence of the attack until Hol and others arrived at the site of the attack on Hbt. Moments later, witnesses saw dolphins thrashing and either a shark or dolphin belly arched and rolling out of the water. At least one adult dolphin and Hbt were observed making body contact with the presumed shark. Hbt was pushed out of the water squirting blood, resulting in a large pool of blood in the water. The commotion ceased and Hbt floated at the surface. Three witnesses went offshore in a small rowboat and a small catamaran to stay with Hbt and Hol. Nic and her calf Nak left the provisioning area within a few minutes. Fin returned to the shoreline. Sur remained about 50 m from Hol and Hbt but left the provisioning area within 15 min.

We approached Hbt and Hol at 1550 in a 4-m dinghy. Systematic data collection on maternal activity and distances from the calf began at 1550. We turned off the motor and drifted with the carcass. The sea was flat (Beaufort 0). Hol remained less than 2 m from Hbt until 1559. She prodded and pushed the floating Hbt upwards repeatedly, approximately every 30 sec. At 1556 she pushed Hbt to the seafloor and held her there for several seconds. Although we had no hydrophones in the water, we could hear loud continuous whistling by Hol every time she surfaced or passed near the boat. The whistling continued until we left at 1709. Hbt drifted about 0.5 km east. Hol continued to circle Hbt at larger distances, periodically returning and pushing Hbt with her rostrum. Intermittently between 1550 and 1612, a shark's dorsal fin was sighted more than 20 m away. At 1620 Hol caught a large fish and swallowed it whole. At 1621 a shark swam towards Hbt and Hol rapidly chased the shark away, remaining <1 m behind the shark for approximately 20 m. At this point we could see that the shark was slightly shorter in length than Hol (who was 208 cm long when measured after her death in 1995), had a large round head and was dark grey, identifying it as a tiger shark. She did not make contact with the shark and the shark veered away from Hbt as soon as Hol approached within a few meters. After the chase, Hol returned and stayed <2 m from Hbt for 4 min. She then began the same pattern of circling at various distances, but never venturing more than 20 m away. We pulled the carcass out of the water at 1707 to determine the cause of Hbt's emaciated state (Fig. 2).

Hbt was visibly smaller than her nephew Nak who was 2–3 d younger. She had a sunken 'neck' and her fetal lines were still visible in early March (Nak's had long since disappeared). Hbt had borne several festering sores on her peduncle since early March. Her swimming pattern appeared to be immature; she often bobbed like a newborn. We observed her apparently trying to nurse from inappropriate body parts, such as sticking her tongue onto Hol's eyeball. Hbt's condition was obviously poor. Necropsy revealed that she had acute bronchopneumonia.

The jaw size and marks on Hbt were consistent with the interpretation that the tiger shark we saw had killed Hbt. When Hbt's carcass was recovered, it

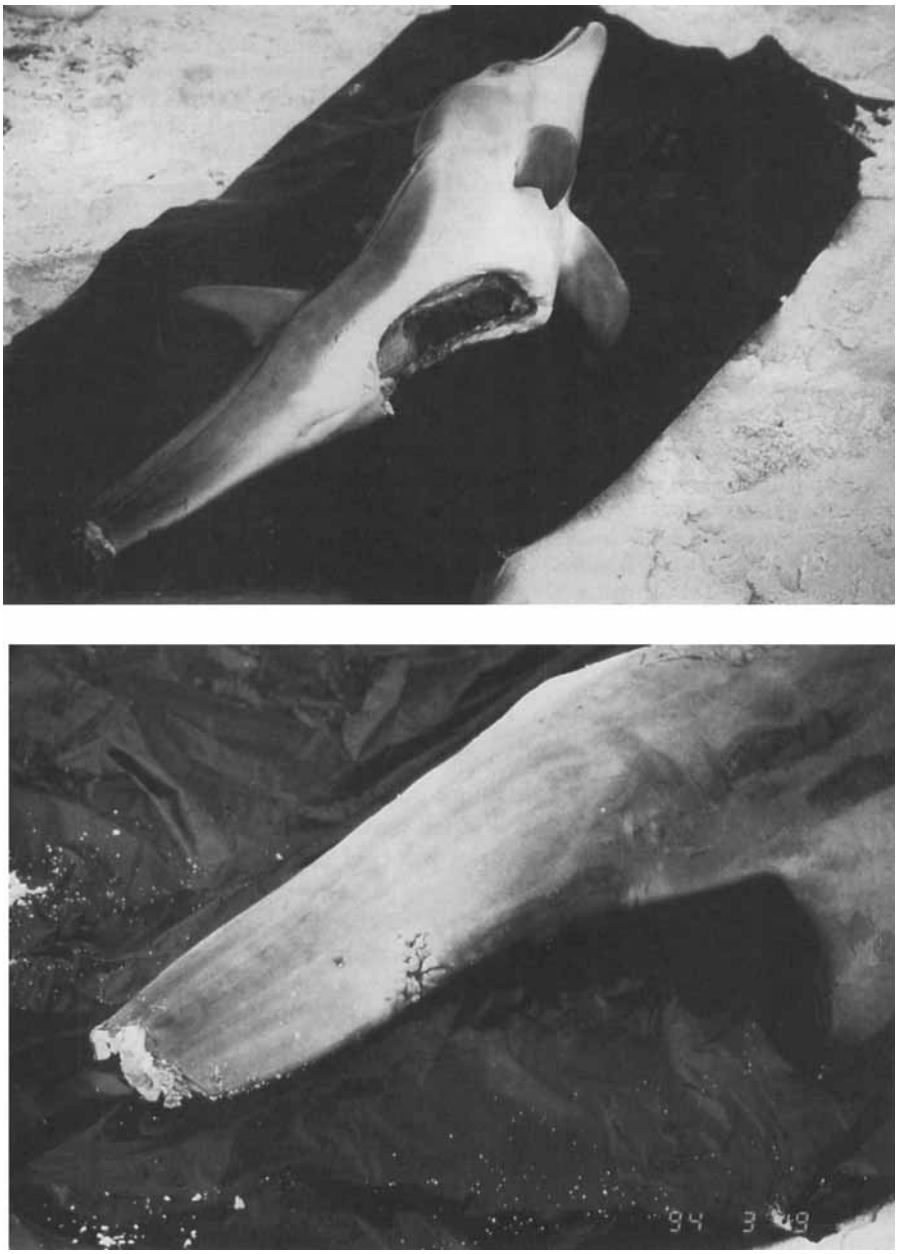

Figure 2. Photographs of Hbt's carcass. Notice sunken 'neck' and sores on peduncle.

had two shark-inflicted wounds: a belly bite and missing flukes (Fig. 2). The dimensions of the shark bite to the belly were 19 cm × 8 cm. Based on photographs of the bite marks, Dr. Colin Simpfendorfer (shark biologist, West Australian Fisheries Department) independently estimated the tiger shark to

Table 1. Mother's behavior and associations pre- and post-shark attack. Hol observed during systematic focal follows away from provisioning beach for 5.5 h (3 follows) in 12 d before Hbt's death, and 5.8 h (5 follows) in 8 d after her death. Mother's activity measured using predominant activity sampling (Hutt and Hutt 1970) at 5-min intervals (calculated from continuous data). Scan samples of group members (10-m chain-rule, see Smolker *et al.* 1992) conducted every 5 min.

	Pre-attack	Post-attack
Mother's behavior (% time)		
Rest	56.1	52.9
Travel (>3 kph)	19.7	17.1
Social	1.5	0.0
Forage	19.7	14.3
Beg (from fishers)	3.0	15.7
Whistling heard	no	yes
Associates (% time)		
Adult daughter and grandson (nursing)	0.0	4.3
Grandson (weaned)	3.0	50.0
Other provisioned adult females	1.5	12.9
Non-provisioned adult females	24.2	0.0
Non-provisioned adult males	0.0	0.0
Non-provisioned juveniles	24.2	0.0

be 170–200 cm long. We hypothesize that the shark initially bit off Hbt's tail flukes and her whistles alerted others. The shark bit Hbt's belly when the other dolphins arrived, thus explaining why no blood was seen until then. Close inspection of Hol, Nic, Nak, Sur, and Fin the next day revealed no obvious scrapes, cuts, or other injuries incurred during their involvement in the attack.

These observations provide clear evidence that wild dolphins will attempt to defend others against shark attack. Observations of the initial attack suggest that several dolphins intervened, albeit too late. After the attack, Hol remained with Hbt and subsequently chased the same or another shark away. Hol was larger than the shark, perhaps explaining her ability to defend Hbt on her own.

Hol repeatedly pushed Hbt to the surface, a common response to calf injury or death (Hubbs 1953, Moore 1955, Connor and Smolker 1990). We interpret Hol's brief pinning of the carcass to the seafloor, a behavior never before observed in Shark Bay, but seen in captivity soon after parturition,[1] as an attempt to revive the calf. Contrary to other views (*e.g.*, those of Cockcroft and Ross 1990), we do not interpret pinning as a form of 'discipline' post-partum or in this particular context. Constant whistling has also been reported during periods of stress, such as when mothers and calves are separated (*e.g.*, Caldwell *et al.* 1990, Sayigh *et al.* 1990, Smolker *et al.* 1993).

A comparison of Hol's behavior and associations during focal animal follows before and after Hbt's death revealed few differences in her activity budget (Table 1). However, after the attack, Hol spent more time near the provision-

ing area, begging from fishing boats and associating with other provisioned dolphins. She did not associate with non-provisioned dolphins in the immediate weeks following Hbt's death. The increase in time spent with her grandson, Fin, was particularly noticeable, from 3% before Hbt's death to 50% of the time afterwards. Hol had never been heard whistling in the weeks before Hbt's death, but she whistled almost continuously right after the shark attack and during the day after the attack. From two to eight days after the attack, whistles could no longer be heard in air. We also observed Hol from shore at the provisioning area for 3 wk preceding (7 h) and for 2 wk following Hbt's death (7 h). Hbt's whistles were often identified during these observations (in shallow water, the dolphin's head is often above water, permitting us to localize the source of whistles), but no whistles could be attributed to Hol until after Hbt's death. After 20 March 1994, Hol's nearly incessant whistling stopped.

Dolphins are not a major component of the tiger shark's diet, but they may still have a significant impact on dolphin behavior and mortality rates. In one study dolphin flesh was found in 1.3% of tiger shark stomachs (n = 558 sharks) caught in a shark meshing program (Simpfendorfer 1992). Sharks, particularly tiger sharks and great white sharks, are estimated to be responsible for at least 2.2% of bottlenose dolphin mortality in southern Natal coastal waters (Cockcroft *et al.* 1989). Of 334 bottlenose dolphins identified in Moreton Bay, Queensland, Australia, 36.6% bear shark scars or wounds, mostly attributable to great white and tiger sharks (Corkeron *et al.* 1987). Over one third of 37 focal calves in our longitudinal study bear obvious shark bite scars, and approximately half of the calves in our study population die before weaning (Mann, unpublished data). Great white sharks have also been sighted in Shark Bay, and dolphins react strongly to their presence (Connor and Heithaus 1996). Large sharks are likely to pose a great threat. Stomach contents of large (>2 m), but not smaller tiger sharks, occasionally contain dolphin remains (Lowe *et al.* 1996). The observations reported here indicate that even smaller tiger sharks may be capable of killing dolphin calves.

With these risks, it is puzzling that calves, from the first weeks of life, travel tens of meters from their mothers for minutes to hours (Mann and Smuts 1998, Smolker *et al.* 1993). At least one demonstrated cost of these separations is enhanced predation risk. Hol's defense of Hbt's carcass suggests that had she been closer earlier, it is possible that the calf could have been successfully defended. Other factors may have contributed to Hbt's death. Provisioned mothers and their calves spend more time separated than non-provisioned ones (Mann and Smuts, in press), and calves born to provisioned females have significantly higher mortality rates in the first year than calves born to non-provisioned females. The exact cause of this difference is unknown, but recent changes in provisioning practices have resulted in lower mortality (Mann, unpublished data). Finally, maternal or calf condition may be a factor. Hol had lost all four (and possibly five) offspring born to her since 1983. Two of the four (including Hbt) appeared emaciated prior to being killed by sharks. Although the prevalence of shark scars on live calves indicates that predation risk is significant, calf condition is likely to increase vulnerability to attack.

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AGE-RELATED CHANGES IN HEMATOCRIT, HEMOGLOBIN, AND PLASMA PROTEIN IN JUAN FERNANDEZ FUR SEALS (*ARCTOCEPHALUS PHILIPPII*)

As part of a long-term study on the ecology, physiology, and behavior of the Juan Fernández fur seal (*Arctocephalus philippii*), the opportunity arose to study hematologic parameters in this species. The present study is the first report on hematology in this species of fur seal.

Field work was conducted at Alejandro Selkirk Island, Juan Fernández Archipelago, Chile (33°45′S, 80°45′W), during the 1992 breeding season (November and December). Blood samples were collected from 12 lactating females ($\bar{x} \pm$ SD, 48 ± 11 kg body mass), 10 juveniles (eight males and two females; 30.2 ± 2.4 kg), and 16 pups (11 females and five males; 6.9 ± 1.5 kg) (Table 1). Pups ranged in age from 0 to about 21 d. The exact ages for juveniles and adult females were not known, but they were estimated to be