Vision and its Relationship to Novel Behaviour in St. Lawrence River Greenland Sharks, *Somniosus microcephalus*

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Rarely observed Greenland Sharks, *Somniosus microcephalus,* were recorded at shallow depths by divers employing underwater video in the St. Lawrence River, in association with a seasonal concentration of Capelin (*Mallotus villosus*) in May-June 2003. We recorded unique proximity-induced display motor patterns in these sharks, which have not been recorded in underwater observations of Arctic Greenland Sharks. Arctic sharks have a high incidence of blindness due to an ocular copepod parasite, *Ommatokoita elongata*. The absence of parasite-induced blindness in St. Lawrence Greenland Sharks, in contrast to endemic blindness in the Arctic population, may allow sharks in this region to more readily visually recognize the presence of conspecifics and potential prey. Improved visual acuity may therefore allow St. Lawrence River sharks to express a different behavioural repertoire than Arctic sharks, with resulting changes in intra- and inter-specific aggression and predatory behaviour.

Key Words: Chondricthyes, Squaliformes, Somnosidae, Greenland Shark, *Somniosus microcephalus,* display behaviour, copepod, *Ommatokoita elongata*.

The Greenland Shark, *Somniosus microcephalus* (Bloch and Schneider 1801) has seldom been observed under natural conditions, and until this report, had been observed by divers underwater only rarely in Arctic waters (Caloyianis 1998). This giant member of the elasmobranch Order Squaliformes is a slow moving, primarily deep water shark reaching at least 6.4 metres in length (Compagno 1984), found in circumpolar regions and in cold, deep water to depths of at least 2200 metres (Herendorff and Berra 1995). Greenland Shark stomachs contain a wide range of prey including marine invertebrates, fish and mammals as well as terrestrial vertebrates such as Caribou *Rangifer tarandus* (Compagno 1984), and the role of this species as a predator, or primarily a scavenger, of marine mammals is controversial (Bigelow and Schroeder 1953; Ridoux et al. 1998; Lucas and McAlpine 2002).

St. Lawrence River Greenland Sharks free of the ocular copepod parasite *Ommatokoita elongate* were observed by divers during an unusual inshore migration associated with seasonal concentrations of Capelin *Mallotus villosus.* Here we report on closely approached sharks that exhibited display motor patterns not previously described in this species.

Methods

We employed SCUBA and underwater video in the region of Baie-Comeau, Quebec, Canada (49°16.9'N, 68°07.2'W, Figure 1), to record Greenland Shark size, sex, physical condition, swimming speed and behaviour in May and June 2003. The occurrence in inshore waters of this elusive species was accompanied by an unusually high seasonal inshore concentration of Capelin (*Mallotus villosus*) massing around docks and bottom structures which was the highest recorded in the region over the previous five years (F. Gregoire, Canadian Department of Fisheries and Oceans, Institute Maurice Lamontaigne, Mont-Joli, Quebec, personal communication 2003). Both juvenile Harbour Seal *(Phoca vitulina)* and Grey Seal *(Halichoerus grypus),* potential prey species of the sharks, were locally abundant and were observed during fieldwork and diving activities.

Observations were made between 09:00 and 17:30 Eastern Standard Time and occurred in seawater depths from 10.0 to 28.0 m (mean=18.1 m +/- 5.8 m 95% confidence interval, CI). Seawater temperatures ranged from 1.0°C to 9.0°C (mean= 4.4°C +/- 3.1°C 95% CI). We employed a standard report form and interviewed local professional divers, who first reported the presence of sharks in the region.

Videotape of sharks was analyzed for size scale using adjacent objects of known maximum size (Plumose Anemones, *Metridium senile*, maximum height of 40 cm) and visible time code (hours/minutes/seconds) to determine swimming speed. We recorded 68.2 video minutes during prolonged encounters with four sharks over a three-day period and documented six other encounters occurring between 26 May and 12 June 2003 in the same region.

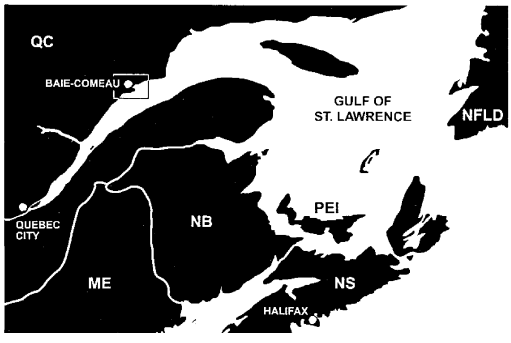

FIGURE 1. Location of Greenland Shark sightings in the St. Lawrence River in the vicinity of Baie-Comeau, Province of Quebec.

FIGURE 2. The rostrum of a female Greenland Shark illustrating typical loss of pigmentation seen anterior and adjacent to prominent nares. The cornea lacking attached parasitic copepods, and the dorsal operculum are clearly visible.

Results

Of the 10 shark encounters, the range in estimated length was from 2.5 to 4.5 m total length (mean = 2.8 m +/- 0.34 m CI 95%). In four sharks sex was determined (3 female, 1 male), with one markedly "girthy" 3.0 m female shark believed to be gravid. In one instance three sharks were seen separately on the same dive and in one instance two sharks were observed simultaneously within 5 meters of each other on diverging courses. Shark swimming speeds ranged from 0.10 m/s to peak at 1.40 m/s (mean = 0.62 m/s +/- 0.31 m/s 95% CI). Greenland Sharks were capable of rapid acceleration from 0.10 m/s to 1.40 m/s and could outpace divers when swimming in a straight line, were highly manoeuvrable and were capable of changing depth and direction rapidly. In one case, the same 2.50 m female shark identified by scar patterns was seen repeatedly over a 3-day period in the same location, in each case within 50 m of the same position when encountered. Female sharks were noted to have more scarring than males, generally linear scarring on the tail, pectoral fins and dorsum of the caudal peduncle. We postulate that these scars may have resulted from nuptial or combat related behaviour, as observed in other shark species (Compagno 1984).

Both sexes exhibited a whitish cruciate pattern which appears to be a loss of pigmentation on the anterior rostrum, and which may be the result of bottom foraging activities using the rostrum (Figure 2). A male shark was noted to have a single left clasper, although this species generally possesses two claspers (Compagno 1984).

During encounters sharks were found swimming approximately 1.0 to 2.0 meters above the substrate towards divers on converging courses, and following close approach swam on sinusoidal courses, in some cases performing complete or half circle manoeuvres over a wide radius (20 to 30 m). These circling manoeuvres resulted in sharks maintaining continuous eye contact with divers, and in two instances sharks left the bottom to ascend upwards at an acute angle and closely approach a diver above them in mid-water, apparently in investigative fashion.

When sharks were closely approached from the lateral or anterior aspect (2.0 m or less from the eye), they initially displayed a motor pattern which included rapid bilateral ventral deflection of the pectoral fins (Figure 3 a, b), deceleration, and adoption of a

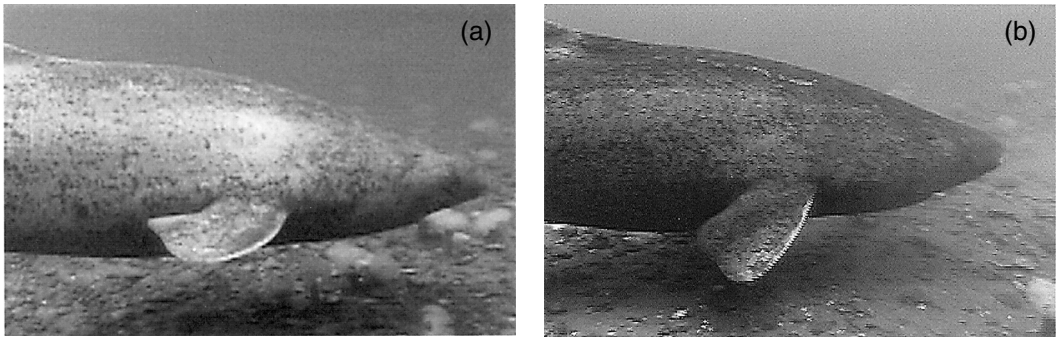

FIGURE 3. Female Greeland shark showing (a) normal pectoral fin position and (b) marked ventral deflection of pectoral fins as part of a motor pattern observed consistently when closely approached by divers.

head-down attitude with the front of the animal 0.1-0.3 m above the substrate, the trunk slanted upward and the tail held higher off the bottom, the dorsum curved upward, the axis of the body being held approximately 10 degrees off horizontal, and the mouth held slightly open (Figure 4). This posture was maintained from one to several seconds, after which the shark would accelerate and swim away from the diver or change course to avoid the diver. This motor display was repeatedly exhibited by the four sharks we observed when closely approached.

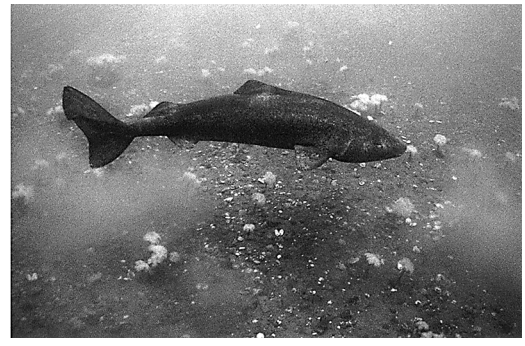

FIGURE 4: Male Greenland Shark posturing, exhibiting curvature of the dorsum, having just shown rapid downward flexion of head and tail, contacting the silt-covered substrate, which caused the visible cloudiness ahead of and behind the animal. This motor pattern was elicited in response to presence and close proximity of divers.

Discussion

Arctic Greenland Shark populations have high infection rates with the ocular copepod parasite *Ommatokoita elongata* (Grant, 1827), which has been found in up to 98.9 percent of individuals in surveyed populations (Berland 1961), and in 100 percent of individuals in a recent tracking study off Baffin Island (Skomal and Benz 2004). Based on histopathological findings in copepod-parasitized eyes, Borucinska et al. (1998) postulated that sharks infected with ocular *Ommatokoita* were likely to be blind. However, the sharks we observed were free bilaterally of external signs and lesions of this parasite, had clear corneal epithelium, showed definite visual orientation to divers, tracked divers with horizontal and vertical eye movement, repeatedly demonstrated visual avoidance of divers and objects on the bottom, and repeatedly exhibited the described behaviour when closely approached. Vision is thought to be a major sense for investigative and social behaviour, prey recognition and predation motor patterns in the majority of shark species (Gruber 1977). The visual acuity of the non-parasitized sharks we observed in the St. Lawrence River may have profound implications for the social behaviour and patterns of predation of this population. The reason these sharks have relatively low ocular copepod infestation rates compared to Arctic populations is unclear, and may relate to parasite abundance and ecology, host factors such as population density, nutrition and immune status, and/or environmental conditions such as dispersion currents, seawater salinity and temperature.

Our perception of this species as a predator of benthic fishes and a sluggish, blind, olfactory scavenger of marine mammal carcasses, with an important ecological role as a mammal "carcass opening" species in Arctic deep water ecosystems (Snelgrove and Smith 2002) has changed as a result of these first-hand observations. Though descriptions of active predation by Greenland Sharks have not been reported in the scientific literature, there is evidence that this species is capable of actively stalking and killing marine mammals as well as scavenging the carcasses of marine mammals. Ridoux et al. (1998) documented a freshly killed juvenile Ringed Seal, *Phoca hispida* (Schreber, 1775), with bite marks across the chest, found in the stomach of a 4.5 m Greenland Shark off Iceland. Our underwater observations support the contention that large, stealthy Greenland Sharks are capable of rapid manoeuvring, moderate speed swimming and potential predation of infirm, sleeping (Ridgway et al. 1975), or predator-naïve juvenile seals. This population of sharks is visual and can avoid or seek divers visually, and using other senses in conditions of poor visibility, and we advise caution when diving under low visibility conditions in areas where these sharks are known to occur. St. Lawrence River Greenland Sharks remain in the same shallow water area for multiple days, repeatedly revisit novel potential prey items in the environment, ascend from the bottom to investigate divers in mid-water, circle and maintain constant visual contact with divers rather than fleeing, and exhibit unusual motor display patterns when approached closely by divers. These findings are consistent with the behaviour of a shark species which has the potential to act as an opportunistic predator as well as a scavenger.

Acknowledgments

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