Site Fidelity and Behavior of Sharks at a Long-Term Shark Feeding Dive Site

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ABSTRACT

To encourage tourism, commercial dive boat operators often offer shark-feeding excursions and provide video footage of the dives to participating SCUBA divers. In a study of Caribbean reef shark feeding dives occurring at a single location off West End, The Bahamas, videotapes of 36 dives recorded over approximately nine years were analyzed. Data was collected on many behavioral and environmental variables. Site fidelity of individual sharks was investigated by documenting, when possible, markings and scars on each shark. It was found that the number sharks per dive, as well as the parasite load, increased temporally. Parasites were most frequently found near gill openings. Bumping of the camera, presumably an agonistic act, was observed more often in females than in males. Males were found to be more aggressive than females during the summer and overall aggression from both sexes decreased over the duration of the study. The frequency of shark feeding attempts was correlated with the technique of the human feeder and showed complex temporal trends. Nine individual females and eight males were identified as appearing in more than a single dive. Although one shark had a hiatus of 4.5 years between sightings, most of the reappearing individuals were repetitively observed on site over periods of several months. Such site fidelity may be attributable to feeding-induced conditioning of the sharks, with possible consequences including ecological disruption and increased danger to humans.

INTRODUCTION

*Carcharinus perezi*, the Caribbean reef shark, is found throughout tropical western Atlantic waters. It is the most common shark on or near coral reefs throughout much of the Bahamas. Like many other sharks, the Caribbean reef shark primarily eats bony fishes (Compagno, 1984). *C. perezi* also has been observed lying motionless on the sea floor (Castro, 1983), a behavior termed "sleeping."

An increasingly popular recreational activity has developed over the past two decades. To increase paying clientele, many dive-boat operations offer interactive shark-feeding dives to recreational SCUBA (and occasionally skin) divers at some of the region’s most popular dive sites ([Fig. 1](#)). Although new regulations prohibit such feeding off the coast of Florida and the Cayman Islands, no such restrictions have been placed on operations in the Bahamas.
The desirability of such shark-feeding activities is the subject of considerable debate. In addition to concerns expressed about ecological disruption, some have suggested that feeding might lead to increased danger to humans (Burgess, 1998). A shark attack upon a submerged human often is behaviorally similar to an attack upon a natural prey item (Nelson, 1977). In other cases, attacks are thought to be the result of agonistic behavior. In such events the shark may exhibit agonistic displays, indicating possible forthcoming aggression. Such agonistic displays have been reported as occurring prior to *C. perezi* attacks on humans (G.H. Burgess, pers. comm.) and are well documented in the gray reef shark (*C. amblyrhynchos*) (Johnson and Nelson, 1973). In the latter species, agonistic displays include:

- head swings well out of the normal path, or upward, yielding a weaving or spiraling pattern in the shark's path
- sharp, quick movements or turns increase in number
- back arches like a cat
- one, or both, pectoral fins are lowered

Another possible agonistic display observed in *C. perezi* is characterized by a brief, but distinctive opening and closing of the mouth, called “yawning” (G.H. Burgess, pers. com.)

**MATERIALS AND METHODS**

A total of 36 shark-feeding dives captured on videotape over the period of 26 November 1992 – 9 September 2001 at a single site off West End, The Bahamas, were analyzed. Many variables concerning the sharks, humans, and environment were recorded. Variables included water visibility; human activity factors; number of sharks and humans per dive; shark parasite load; gender of shark and male maturity; and frequency of feeding attempts, acts of aggression, and “yawning.” Human activity factors included the total number of submerged human divers as well as the feeding technique employed by the human feeder, feeder aggression towards sharks (as measured by spear jabs), and identity of the individual feeder. Only agonistic displays by sharks occurring prior
to feeding were recorded. These acts included a circling or “zig-zag” swimming pattern, back arching, dropping of the pectoral fins, and “bumping.” Bumping is characterized by the shark’s head making contact with the video camera lens (Fig. 2). Site fidelity of individual sharks, the tendency for a shark to return to the same location, was investigated by documenting, whenever possible, markings and scars on each shark. Scars on males and females, the latter resulting from bites from males during the mating process, were particularly useful for identification. The presence of claspers, a reproductive organ in males (Fig. 3), served to differentiate the sexes and clasper size was used to estimate male maturity. In tandem, size, sex and scarring patterns served as the statistical basis for establishing a minimum number of sharks. Parasite abundance and location on the body were recorded.

![Figure 2. Bumping, an antogonistic act.](image)

![Figure 3. Male claspers.](image)

**RESULTS**

The number of sharks per dive was found to increase significantly over time (Fig. 4) (male p=0.0025, female p<0.0001, overall p<0.0001). The sex ratio of observed sharks was 145 males: 133 females. Most (93.8%) male sharks were mature.
The frequency of feeding attempts made by sharks remained constant. However, because the number of sharks participating on dives increased over time, the frequency of feeding attempts per shark per dive decreased temporally (p=0.0036). The number of agonistic acts per feeding attempt decreased over time (p<0.0001) (Fig. 5). Among agonistic acts, lowering of the pectoral fins was observed most frequently, followed by zig-zag swimming and circling at similar frequencies. Back arching was only observed once. During the summer, males were significantly more aggressive than females (Fig. 6) (p=0.0424). However, females bumped the camera more frequently (p=0.0304), with females and males averaging at 0.0685 and 0.0460 bumps per minute, respectively. Yawning was recorded on five occasions. Frequency of aggression was dependent on the feeding technique used (p<0.0001). Feeding the sharks by placing the food on the end of a long spear yielded the most aggression, whereas placing the food under a reef ledge produced the least aggression (Fig. 7).
There was no correlation between frequency of agonistic acts and individual human feeders. Furthermore, the feeder did not change his frequency of jabbing the sharks with a spear, therefore the aggression towards sharks by the feeder remained constant. Water visibility and human aggression towards sharks did not affect shark behaviors. The relationship between number of human divers participating on a dive and frequency of shark feeding attempts was curvilinear ($p=0.0587$) (Fig. 8), with frequency of feeding attempts peaking at fourteen divers.
Parasite load increased temporally ($p=0.0002$) (Fig. 9). Of the total number of parasites recorded on sharks, 83.59% were found near gill openings, 6.70% were located on the first dorsal fin, and 9.71% were seen on other parts of the sharks. Females hosted a heavier parasite load than males ($p=0.0653$), with the mean number of parasites on males and females being 0.0282 and 0.0372, respectively. Four male Caribbean reef sharks were also observed with bulging “lumps” on their left flank in approximately the same location.

Sharks showed a notable degree of site fidelity (Fig. 10). Nine individual females and eight males were identified as present on more than a single dive. Although one individual had a hiatus of 4.5 years between sightings, most of the reappearing individuals were repetitively observed on site over periods of several months. A single Caribbean reef shark of unidentified sex was observed sleeping on the ocean floor, concealed underneath a
natural reef arch (Fig. 11).

In addition to Caribbean reef sharks, nurse sharks (*Ginglymostoma cirratum*), two great hammerhead sharks (*Sphyrna mokarran*), and one lemon shark (*Negaprion brevirostris*) were observed.

**DISCUSSION**

The results suggest that sharks were conditioned to feeding at this site. Since the number of sharks observed per dive increased temporally, it appears that sharks recognized the area as a feeding-site and oriented to that locale. The site fidelity of numerous individuals reinforces this conclusion. The decrease in aggression further suggests that the sharks are becoming more familiar with the feeding procedures and their surroundings. Since the human feeder did not significantly change his frequency of aggression towards sharks, more confidence can be placed on these interpretations. Although sharks are less aggressive during the dives as a result of conditioning, if feeding is denied, danger may be posed to unknowing submerged humans at the feeding site or in adjacent areas frequented by the sharks.
The increase in parasite load may be a result of increased shark density with parasites more readily transferred between hosts. Such a marked change in parasite load underscores concern about ecological disruption. By inducing the congregation of many Caribbean reef sharks through feeding, shark-feeding operators may be changing the natural biology of the sharks and promoting parasite transfer.

It was found that a relatively constant number of feeding attempts occurred during the period of an individual feeding dive, regardless of the number of sharks present. Since the number of sharks increased over the course of the study, the individual feeding rate (number of feeding attempts per shark) decreased. Thus, the amount of food each shark consumed during a feeding event decreased over time. In addition, if a social hierarchy develops in which certain individuals are excluded from access to provided food, then the potential exists for an increased number of hungry, aggressive sharks in an area, potentially leading to negative interactions with humans. Feeding also raises concern about ecological disruption. The diet the sharks were consuming over the course of the study was inconsistent and may potentially result in nutrient deprivation.

A hierarchy of agonistic displays may be postulated from the relative percentages of each act. If the most frequently observed display is interpreted as the initial indication of aggression, then dropping the pectoral fins is the initial display. Zig-zag (Fig. 12) or circle patterns of swimming would follow in the hierarchy, followed by arching of the back. Yawning displays were rare and not seen prior to feeding, suggesting that this behavioral pattern may follow the above displays hierarchically. Further investigation of agonistic display is required to confirm this suggested hierarchy.

Females may react towards threats more actively than males, as they were observed to bump the camera more frequently. Female Caribbean reef sharks are generally larger than males, possibly leading to this increase in aggression. Although much remains unknown about the reproductive behavior of *C. perezi*, its mating season can be postulated to occur in the summer, since males were found to be more aggressive during this season.

The results show that average shark aggression can be predicted by the type of feeding technique used, and that it is not the feeder himself to which these sharks are responding. Placing food on the end of a long spear yielded the most aggression whereas placing the food under a reef ledge yielded the least aggression. This predictive
power may be useful to other shark-feeding dive operations as to prevent shark aggression towards divers.

Finally, the observed “sleeping” shark was one of the few documented sleeping *C. perezi* in the waters of the Bahamas, further discrediting the myth that sharks must be in constant motion. The lumps observed on the left side of male sharks could be a result of some physiological condition or an endoparasite.

The research was a retroactive design, thus only a minimal level of statistical constraint on variables was possible. Data gathering was limited by the quality and content of existing video tapes, which posed various limitations. For instance, as technology improved over time, visual acuity improved and more individual sharks could be identified. Although statistical procedures can help eliminate such confounds, the project would have yielded more confident results if the research plan had included scientific field videography protocols.

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**FOOTNOTES**

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**REFERENCES**

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