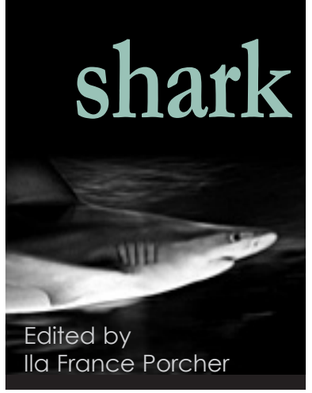


Cognition in Sharks

Text by Ila France Porcher. Images by Ila France Porcher, Wolfgang Leander

A difficulty in obtaining information about wild animal behaviour is that detailed observations of different individuals is necessary over long periods of time, and this is especially hard to achieve with sharks. But in the shallow lagoons of French Polynesia, such observation was possible without the encumbrance of scuba gear, and without the problem of the shark disappearing into the depths. Over a period of 15 years, I searched out and observed reef sharks in the different locations where I lived there, and for seven years, studied them intensively.

As I learned where and how to look for the local sharks, I focused on blackfin reef sharks (*Carcharhinus melanopterus*), because they were so easy to find patrolling the shores. But other species, including whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), sharptooth lemon sharks (*Negaprion acutidens*) and nurse sharks (*Ginglymostoma cirratum*) were present and often observable for long periods, too.

As time passed, I learned to put them at ease with me, they became accustomed to my presence, and accepted me into their community. By recording the actions of the various individuals, I was able to access a dimension of their lives that had not previously been documented.

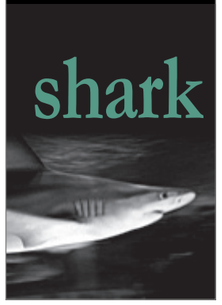
Individual differences

Individual differences marked each shark's behaviour. Each one had a unique pattern of roaming, under the dual influences of the lunar phase and the reproductive cycle. Some were nearly always present in their home ranges, while others travelled for months at a time. Individual sharks demonstrated different rates of learning, and they varied greatly in their responses to different situations. They had complex social lives, and their behaviour showed a flexible intelligence.

In time I concluded that they were using cognition rather than reacting automatically to stimuli. This was the reason that I spent so much time observing them, and following the precepts of cognitive ethology, tried to learn what they were like as animals and individuals.

ILA FRANCE PORCHER

shark tales



Cognition is the term used for thinking in non-human animals—the process of knowing through thinking. An animal shows that it is using cognition, rather than trial and error, when it must have referred to a mental representation in order to act as it did. Many life forms, including invertebrates, are increasingly found to be using cognition in their daily lives, and cognition in fish has been well studied.

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Knowing others as individuals

The sharks recognized each other as individuals, which is the prerequisite for the complex social lives in which cognition is most evident. They tended to travel with preferred companions, and these sets of friends joined with wider groups of sharks at times. Due to the circular paths in which they move, they repeatedly crossed each others' scent trails, and thus remained in loose contact as they roamed, together, yet not usually within visual range.

Companions were individuals of the same gender, and usually the same age as well. Some sharks usually travelled alone, some always with the same companion, and others changed companions relatively frequently. Often, travellers were temporarily joined by sharks residing in the regions through which they moved. There was always excitement when travellers and residents met. They would follow each other around and swim side by side for long periods, before the companions moved on together.

As far as I was able to determine, such friends came from the same region. The reef sharks were acquainted with the other individuals whose home ranges overlapped theirs; travelling companions were usually neighbours at home.

Bonnethead sharks, too, have been shown to recognize each other as individuals, and it has been documented that at least some species of sharks and rays choose their mates, providing further evidence that individuals know each other.

Memory and learning

Learning plays an important role in the lives of sharks, as has been well documented. Learning is closely involved with memory, and the sharks I had under observation frequently showed their ability to remember events far back in time. Familiar sharks recognized me in the lagoon as much as two years after their last meeting with me, and their behaviour, of greeting and swimming with me, was unchanged.

Like people, different sharks had different rates of learning. For example, among those who accompanied me most often, one of them never learned to take a treat I threw for her, while only a few caught on immediately without practice.

Vigilance

Wild animals are always vigilant, always on the look-out for danger, and sharks are no different. Whenever anything was different about my visit, whether it was in a different place or at a different time, the sharks' behaviour became more cautious.

When I brought a second person with me, which happened very rarely, they initially vanished beyond visual range after a swift approach when I first appeared underwater. Many minutes passed before they reappeared, usually approaching the stranger first, in long lines led by the boldest among them. This initial disappearance never happened when I was alone, and demonstrated their alertness to changes, and their ability to make quick decisions based on unexpected findings.

Those who complain that shark feeding dives cause sharks to harass spear fishermen, have failed to understand this crucial point—sharks easily discern the difference between a shark feeding event and a spear fisherman. It is the fishermen themselves who attract sharks, by holding dying fish underwater and trailing scent.

Approaches

All of the species of reef sharks I observed habitually used the veiling light to conceal themselves. Once out of sight, they often continued to pay attention to events from beyond visual range, by listening and through their lateral line sense. Sometimes they passed into view for a brief look just at the visual limit, then vanished again beyond their curtain of blue.

The diagram (above) shows the general pattern of approach of a

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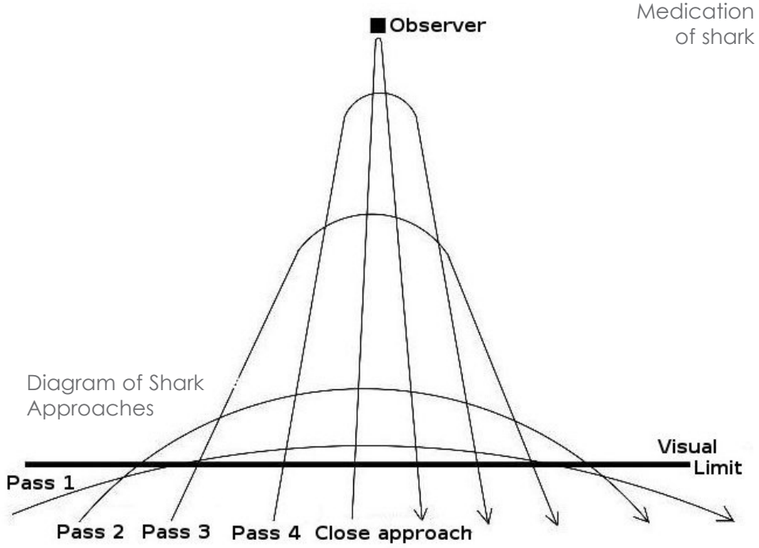
THIS PAGE: Blacktip reef sharks

shark tales



Medication of shark

Diagram of Shark Approaches

blackfin reef shark.

Initially, the shark curves briefly into visual range, then out. A few minutes later, it appears again for a closer look. With each repetition, the arc becomes more acute until, if the shark is very interested, it approaches nearly head on.

Any variation on this pattern could occur. Shy older females often lingered out of visual range before making one or two passes into view, but never came close, while males coming into the lagoon in exited bands to mate after sunset, often omitted the 'cautious passes' phase, and zoomed straight up to me.

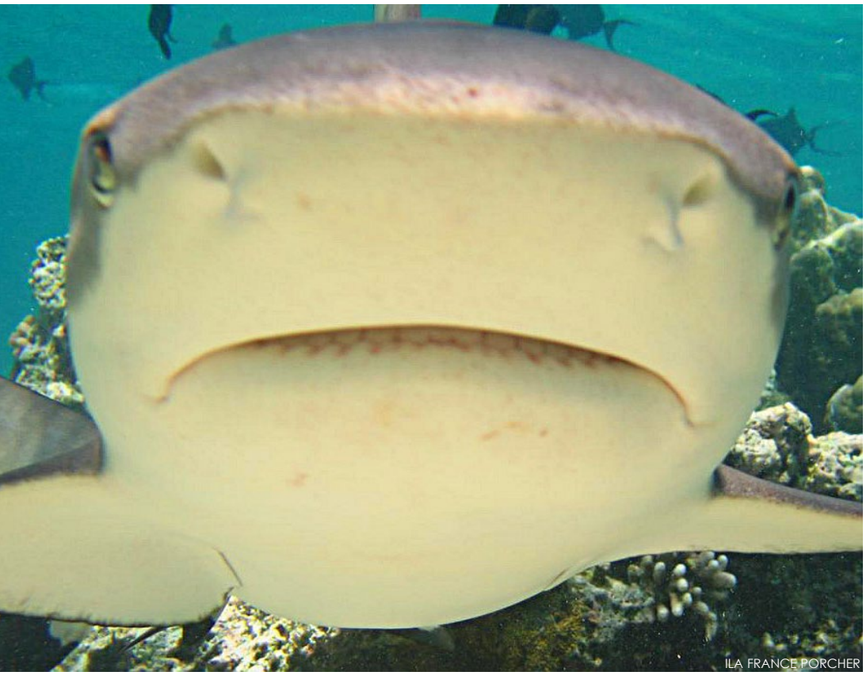
Other species showed a similar general pattern of approaching, but their closest approach came more from the side than head-on.

Hiding

Often a shy shark who appeared briefly in visual range would suddenly pass close behind me, but dart away if I turned and saw her—she had come to look without being seen. Sharks had no trouble recognizing frontal views, and they understood the direction in which a person was looking. In other ways, too, they showed that they were aware of whether or not they could be seen. When I was with another person, for example, they always swiftly approached if we raised our heads above the surface to talk.

Once I was swimming with my step-son, and he climbed on a dead coral structure to look around above the surface. The shark who was accompanying us swam over to sniff his legs, and with his head above the surface, the boy never saw her. Sharks even surprised me by swimming between my face and hands when I was drawing, which never happened when I was paying attention to them. One unusual shark passed me nearly every time I went to the lagoon, drifting by from left to right, always and only when I was looking the other way. She did this for eight months before relaxing her vigilance and moving around me more freely.

Always on the alert, the sharks used their awareness of whether or not a person could see them to their advantage. Therefore, it is not surprising that it is said that you never see the shark who bites you. As with other predators, it is best to face them, and pay attention to them when you are with them. But, that said, shark bites are very rare, and sharks were the only wild animal with which I was in intimate contact for many years—which never did bite me, either through accident or irritation. My conclusion in the end was that an inhibition against biting companions was at play.



Close approach by a shark

Attention, curiosity and observation

The sharks were very curious, and investigated anything new. If a coconut floated across the surface, one would notice and rise to sniff it, followed by the others. They would often follow me for long distances, sometimes for hours, while remaining hidden beyond visual range. From time to time, I checked to see who was with me by suddenly stopping, whereon they came into view. It was surprising that they would remain concentrated on one thing for so long.

Sometimes unexpected events revealed patterns I might not otherwise have seen. When one of the sharks became ill, each evening I tried a different tactic to give him a piece of food in which I had inserted antibiotics. The other sharks seemed to anticipate each of my attempts, and their actions made it very difficult for me to medicate him.

One of the tactics they used after several nights of missing out on the food, was to wait beyond visual range. When the time came, and I went to the kayak and threw the food into the water, seven sharks whom I thought had left an hour earlier, soared in, and the fastest one snatched the treat in mid-water.

Since they had been out of sight, they had based their decision to act on a signal they had heard. They had understood the sounds of me getting the treat and throwing it, and their actions were effective, because one of them did get the food! This example shows their ability to predict something that might occur in the future, and to concentrate on it. Cognition is indicated because they must have held a mental representation of food coming under such circumstances, the signal that would trigger its imminent arrival, and what they planned to do when it came.

It often seemed that the sharks tried to be one step ahead of me. In long-evolved predators who catch swift and evasive fish for a living, the strategy of watching and waiting, and trying to predict from past experience what the prey would do next, could well have been selected for.

Self-awareness

Cognitive ethologist Donald R. Griffin pointed out that when

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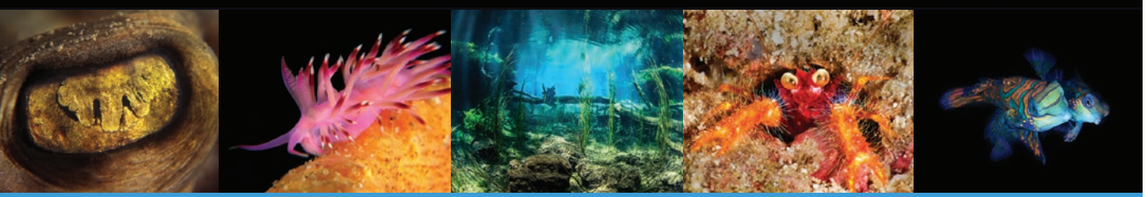

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Sharks passing into view

an animal hid itself from view, it was demonstrating self-awareness. He described how Lance A. Olsen had reported that grizzly bears sought places from which they could watch hunters while remaining hidden. Other observers had reported too, that bears tried to avoid leaving tracks. The researchers concluded that these bears were aware of being present and observable, as well as creating effects□their tracks□through their movements, which could be seen by others.

The sharks' habitual way of remaining concealed behind the veiling light until an opportunistic moment, or approaching from behind to avoid being seen, is in the same category of behaviour, and indicates that they are aware of being present and observable. This is the reason why the so called 'shark counts' divers are asked to participate in, have no scientific validity. Since sharks are either attracted to divers, or avoid them, the numbers of sharks seen by divers are not representative of the true numbers on the reef.

Where sharks are habituated to divers and come to see them, such counts may give the impression that there are many sharks, when actually, their numbers are few. Shark finners are attracted when the information is publicized, and the dive site is fished out.

Decision making

Occasionally, reef sharks would flip on their backs to wriggle in the sand, presumably to scratch or to free themselves of parasites. On other occasions, a shark would turn to whip the side of its body against a sand bank. The floor of the lagoon was made up of sand interspersed with reef flats and coral, and the sharks invariably chose only sandy places for such manoeuvres.

Sometimes a shark carefully positioned himself to use a smooth, flat surface of dead coral on which to rub himself. Apparently, he had intentionally surveyed the environment and chosen a suitable structure to use. He must have held a mental image in mind of what he wanted, and referred to it while looking for a formation of the right shape.

Though this may not seem to be very impressive in terms of thinking in sharks, the availability of surfaces to use in this way doesn't mean that the animal will realize how they can be of benefit.

For example, mynah birds (*Acridotheres tristis*), and junglefowl (*Gallus gallus*), the wild ancestor of domestic chickens, both spend much of their time foraging for insects on the ground, and both have strong feet for walking. However, mynah birds haven't discovered that they can use their feet to help them uncover these insects, while junglefowl do so instinctively.

I was lucky to witness a clear decision made by two sharks, between two possible choices. One day near my study area, the fins of several blackfins were slicing through the surface, and underwater, fish were spawning, and sharks were gliding among them, occasionally snapping

shark tales

one up.

Two came over when they saw me, and returned from time to time to circle me over a 15-minute period. When I left and travelled another half a kilometre into the lagoon, these two sharks followed from the spawning site.

They decided to follow me even though they had not seen me for several months, and they made the choice that was based on a mental reference, a thought or memory, that sometimes I brought food. Yet, they were in a situation in which they could see, hear and smell food, moving in a stimulating way, and I had not fed them in that location before.

Such memories of events that can be called upon for decision-making, are called declarative memories. It is now thought that they cannot be used in the absence of consciousness.

Communication

I could not see evidence of communication between sharks except through body language. If you have ever met an aggressive shark, you will know how well body language communicates at a physical level. The response arises deep within us without any interference from the frontal lobes of the mammalian brain!

Occasionally, companions acted in concert, leaving the other sharks, and swimming in formation to perform a specific act together. How they communicated the decision to do this was not clear, but likely body language played a role.

In his book, *The Secret Life of Sharks*, Professor Peter Klimley described how great white sharks ritualize their conflict when a seal, which one of them has killed, comes under dispute. Each slaps the water at an angle with its tail, and the shark who raises the most water and blasts it farthest wins the prey. For this ritual to be effective, each shark must view its opponent's gesture as a communication, and understand it, since the winner gets the seal without a fight, which could badly hurt both sharks.

Scheduling

Sharks often passed the same place at the same time on consecutive occasions. One young visiting male passed by my observation post about five meters to the right, between ten and 15 minutes after sunset each night for several weeks. Each time, he saw me and came for a closer look, then turned and went on his way. Another rare visitor's first four visits, though months apart, occurred precisely at the moment that the sun touched the horizon, four days before the dark of the moon.

Intrigued, when one of the residents who had habitually met me on my arrival in the lagoon, began coming instead at the end of the feeding session, and missing out on the food, I kept careful track of the time of her return. For reasons known only to her, she had suddenly begun to spend her days in the ocean. Over a period of many months, she returned about ten minutes before sunset, night after night. Sometimes, she still met me when I arrived, yet other times, I saw her return from the sea when it was nearly dark, passing in the distance, and not coming to the feeding session.

Besides illustrating a remarkable ability to follow a daily schedule, and yet be flexible about it, her actions indicated that she had not become dependant on my weekly feeding sessions, though she had known about them since she had been a juvenile.

The sharks seemed to have no trouble catching a fish when they wished to, and often came to the feeding sessions only to socialize. Resident sharks routinely left for months at a time, and visitors did not remain in the area because of the food. Though many came to my feeding site at the proper time, their long-term schedules were unaffected by the few scraps I provided weekly to facilitate my observations.

Social learning

The resident sharks learned, in time, that the fish-scraps I brought to the feeding sessions were in the back of my kayak. Though this species has not been documented breaching the surface to eat or to look around, these sharks found that the food could be accessed by leaping from the water and leaning towards the boat, while snapping at whatever they could locate. The sound of their jaws snapping shut made loud clapping sounds, and some of the kayak's straps were cut, punctured and sliced by their sharp little teeth.

This behaviour pattern, which was a new foraging technique, was initiated by one or two sharks and instantaneously copied by the others present. Later it was repeated by the sharks in that group. This discovery occurred twice, in different locations, under different circumstances, with different groups of sharks, and is an example of social learning, which is basic to the development of culture.

Under normal circumstances, the space above the surface is not something that these sharks

shark tales

Lemon shark

WOLFGANG LEANDER

would have reason to consider. But they were presented with an artificial situation in which I came from above the surface and returned there, and so did the food in which they were interested.

They would doubtless have stored memories about the surface from the occasions, particularly when they were small, when they swam through it or up against it while chasing a fish, though it is unlikely they could have formed more than a vague impression that there was a space above, from such brief events. Yet, their behaviour suggested that they were aware of a volume above the surface in which things could exist, and from which I came and went.

A question in cognition is whether an animal knows that something continues to exist when he or she can no longer see it. An object apparently ceases to exist for dogs, for example, when it goes out of sight. So few people would agree that sharks could understand that I was in the boat, even when I had just left their company and climbed into it. Yet they were aware.

Could they see me through the surface? It often appeared that they could, and when they raised their heads from the water, they raised them straight towards my face as if they could see it from beneath. Once their faces were in the air, they could certainly see me there in the mysterious volume above the surface—great white sharks are known to deliberately look around above the surface.

The electro-sense works at close range, and possibly continued to inform them that my living body was just beyond the plastic hull when I vanished. Further, they could hear the sounds of my movements in the hollow craft with their lateral line sense and sense of hearing, a way of perceiving the environment that appears to be dominant in sharks.

If the sight of me underwater was replaced by the sound of my movements in the hollow plastic kayak as I got in, these perceptions could well continue to inform them that I was still present, even though their view of me was blocked, just as it was blocked whenever they listened to me underwater, from beyond visual range.

Indeed, the many ways that sharks took advantage of the opportunity to hide behind the veiling light, and to approach when they were not visible, such as when a person's face was above the surface, strongly suggests that they are quite comfortable with the idea that something continues to exist, in spite of being out of sight.

Sharks have exquisitely coordinated senses, and their behaviour indicated that they used this sensory input alertly to make moment-to-moment decisions, and respond flexibly and appropriately to changing circumstances. They remembered the events in their lives, and referred to these memories to make decisions.

They were curious, but cautious, and learned quickly. Their versatile behaviour, individual differences, and different ways of handling various circumstances, were not indicative of a set of stimulus or response reactions. Yet, distanced so far from us in evolutionary time, the motives and true states of subjectivity experienced by sharks must remain mysterious.

I have observed other species, including bull sharks and tiger sharks, for shorter periods, and found that their behaviour was remarkably similar to the behaviour of the requiem sharks, far off, but not too distantly related, whom I had known in Polynesia. This is to be expected since sharks have been evolving for approximately 420 million years, and many species travel widely and are found around the globe.

The essential qualities that sharks evolved to be so successful would already have developed in the ancestral forms, before they evolved into modern species occupying the ecological niches we know today. There is no reason to assume that the Polynesian sharks were different. It is more probable that they were ordinary sharks, quite representative of their kind.

Though fish may seem primitive when looking down on them from the altitude of Homo sapiens, in fact they are highly complex and evolved life forms. And no brain is simple, as anyone who has observed the activities of a spider will appreciate. □

Ila France Porcher, author of My Sunset Rendezvous: Crisis in Tahiti, *is an ethologist who focused on the study of reef sharks after she moved to Tahiti in 1995. Her observations, which are the first of their kind, have yielded valuable details about their lives, including their reproductive cycle, social biology, population structure, daily behaviour patterns, roaming tendencies, and cognitive abilities. Her next book,* On the Ethology of Reef Sharks, *will soon be released.*

WOLFGANG LEANDER

Lemon and tiger sharks