Chapter 4

The Importance of Academic Research in the Field of Shark-Human Interactions: A Three-Pronged Approach to a Better Understanding of Shark Encounters

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Additional information is available at the end of the chapter

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Abstract

One of the least understood areas of shark research is the interaction between animals and humans, from factors influencing face-to-face encounters to the causes of incidents and behavior patterns. Although some of these questions can be addressed through studies outside of the water, most interaction-related questions have to be tested by direct observation of the sharks. The main goal of our research is to better understand sharks, and what influences them the most when they are in the vicinity of a human being. Our improved understanding of this animal substantiates the notion that sharks are no different from other animal species and do not reflect the still too often presented media monster. Understanding the true nature of this animal transforms this wrongfully described creature into the rather shy and intelligent animal that it truly is.

Keywords: behavior, body language, shark, shark bites, shark-human interaction

1. Introduction

The possibility of the presence of a shark can easily enter a person's mind when entering the sea for recreational activities, such as swimming and surfing [1]. For most people, the thought of encountering a shark is frightening and has become even more so due to sensational media coverage, and since we were shown very clearly in the movie JAWS how things could turn out when a person meets a hungry shark. But despite the impact of gory movies, media exaggeration and the fact that most people understand that such encounters are different from movies like JAWS, rational thinking still ceases to exist in the presence of a shark and a single thought occupies the mind; how to get away from a shark as quickly as possible and get out of the water.

Despite the fear of a potential shark encounter when people decide to enter the water, the proper response of how to withdraw effectively in such a scenario is not well known [2]. Unfortunately, the plethora of unsubstantiated suggestions flooding the literature [3–5] and Internet make the knowledge of how to correctly interact with a shark and identification of the correct, and more importantly, well-tested ways of leaving the water without getting harmed more than just the proverbial needle in the haystack.

These types of situations are addressed in the field of experimental shark-human interactions. Whenever an interaction between a human being and a shark occurs, knowingly or unknowingly, from a person's viewpoint, this type of research explores the core of this type of event. Shark-human interaction studies address various questions, from the validity of the "mistaken identity theory" [6, 7] to the interpretation of wound pictures [8, 9], and approach pattern and body language of sharks in the vicinity of humans [10, 11]. Despite the broad spectrum of questions in this research field, it mostly boils down to what the intention of these animals are while in the vicinity of a human being. Although we will never be able to know for sure what a shark truly thinks, experiments and analytical tools can be used to get as close as possible to the true intention of a shark during such circumstances [12].

The following sections reflect a summary of our research within the shark-human interaction field. Behavior identifications and forensic analyses as well as the various aspects dealing with the human mindset will highlight the most important findings and show how these findings can improve the way a person thinks and acts when it comes to interactions with sharks.

1.1. JAWS is not out there

For decades, sharks have been falsely portrayed by the media more than any other animal [13–15]. The movie JAWS, which was released in 1975, has been by far the biggest influence on public perception of sharks. One of the main reasons why this movie was seen as representative of the nature of sharks was that scientists in that era were not able to counter this general opinion with factual evidence. At the time, very few scientists were studying sharks, and nobody specifically worked in the field of shark-human interactions [16]. Due to these shortcomings, the media had a free rein in their representation of these animals. Granted, today's mainstream media has taken some steps to correct this wrongful image, roughly half of all stories in the media still portray sharks negatively, thus making it impossible to reverse the falsely negative image of these animals. For example, a reflection of this perception is the nearly nonrestricted industrial fishing that led to dwindling shark populations. Sharks are still mostly seen as dangerous and so protective measures are either up to this time nonexistent or not effective enough [17–19]. People tend to follow the old adage that they do not need to protect what they are afraid of. Indeed, ignorance and arrogance have led to the elimination of other animal groups in the past [13, 20], and sharks are in similar danger.

Probably, the most important tool in how to change the attitude of the public is not just education but should specifically address our needs of sharks, and the ticking ecological time bomb which needs to be defused now [21, 22]. It is also to show that we do not have to be afraid of sharks, despite what movies, the media and the lack of scientific knowledge in the 1970s

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and 1980s made us believe [16]. Understanding animals means spending time observing them closely and trying to comprehend the flow of information between humans and sharks, which can only occur when studying them in their realm. One of the most prominent aspects of any interaction with a shark is the unknown factor of what a shark "does" in a person's vicinity and the reasoning behind these actions [10–12]. Understanding these interactions and the factors influencing these situations are paramount during every activity. However, these scenarios are not frequent, and it remains challenging to collect meaningful research data by just interacting with these animals without setting up some kind of experimental protocol. Thus, it is crucial to create scenarios in the shark's habitat that allow proper scientific evaluation [10–12].

It is not just an understanding of key factors that impact these interactions that is needed, but it is also necessary to examine the variety of nonhuman-oriented behavioral patterns exhibited by sharks, in order to achieve an accurate description. Behaviors seen in sharks such as gaping and chafing are triggered by a variety of factors [23–25] but are not caused by humans, even if they may be close by.

Besides setting well-defined parameters of data collection methods during testable interactions, it is also necessary for the observer to have a detached mental state, as long as it is not at the core of the experiment. Fear affects people on different levels [26, 27], but when it comes to sharks, fear needs to be addressed more than ever since it likely affects the very scenario that is being investigated [28–30]. Although fear most often ceases to exist, once people get used to sharks [2], it can remain present on different levels. Although most of a person's basic fears are projected onto the shark, it is mostly the fear of not knowing how the situation with a shark will develop, and which factors influence the situation, as well as what has to be done, if necessary, that dominates and controls the scenario [2].

In the following sections, we will briefly describe the different behavioral and approach patterns of sharks close to humans, how factors underlying them will influence the scenarios and give an overview of the main behaviors we found. Furthermore, we provide an outlook of how forensic bite analysis and how bite rates along shorelines can be used to complete the picture of the shark that we should spread. Shark-human interactions consist of many facets, and even though we have only just begun to scratch the surface, the emerging picture already reveals a much different image than is so often presented in the mainstream media.

1.2. What is it with surfers and sharks?

Surfing and sharks is a commonly discussed topic along many of the world's beaches with the general assumption that sharks, especially white sharks, mistake surfers for seals being the main cause of incidents [31, 32]. It is true that surfers are the most exposed group when it comes to contact with sharks [33], but the idea of a mistake, as a cause for bites, is not true [6, 7]. We have shown that there is no mistake when a white shark bites a surfer [7]. It mostly happens because the shark does not know what a surfer is, and therefore exploration is the main cause for these bites. Indeed, exploration is also the basis of many other interactions between humans and sharks that end in a conflict [8, 9].

In order to establish exploration as the main cause for white sharks biting surfers, we needed to compare board damages and wounds on surfers with the wounds on pinnipeds, especially seals, which are the white shark's usual prey [34–36]. It was not just the actual outcomes that were important, but we also had to understand the white shark's mindset as it grows up and is confronted with pinnipeds. Pinnipeds are highly agile mammals and demand tremendous hunting skills if a shark is to catch them [37–39]. Although adult white sharks are very effective hunters, when they are small or young, they are far from capable of catching these pinnipeds [31]. Thus, in order to be successful, white sharks need to reach a rather large size, at least 3.5 m, before they are effective at catching this prey [36]. Even then, their success rate remains rather low.

If the assumed "mistaken identity theory" was true, the minimum size of white sharks targeting surfers would be similar to sharks that hunt pinnipeds. However, our research showed that the sharks involved in bites on surfers are often much smaller than this, even less than 2.5 m in length. To reconstruct a white shark's size, we needed appropriate references from the wounds or board damages, preferably adjacent tooth imprints. Since there is a strong correlation between a shark's length and its interdental distances, the measurements taken from surfer wounds or damaged boards allowed us to accurately estimate the size of the white shark involved [40, 41].

Both the size of the white sharks involved in surfer incidents and the severity of the damage done to the body or board were important factors. Bites on pinnipeds are executed with tremendous force by a white shark to prevent the escape of the targeted prey. Therefore, if attacks on surfers were due to a case of mistaken identity, the wounds on surfers and/or board damages would also be expected to be extensive. To investigate this, we created a severity index that allowed the degree of the wound and board damage to be assessed. The scale ranged from 0 to 5, with 0 being the most superficial and 5 representing the most extensive damage to a person or board. If a mistake was the cause of an incident, it could be assumed that the damage would be very high, at least level 4. Nevertheless, we obtained an average score of 1.8, indicating a quite superficial level of damage, certainly insufficient to prevent an escape should the surfers indeed have been pinnipeds. Both of our results, smaller sharks initiating a bite and the rather superficial damage caused, indicate that these incidents are not the result of a mistake, but that the shark purposely initiated a bite with the likely motivation of getting more information of what a surfer might be. Two-thirds of all bites were superficial in nature, and the remaining one-third either were more severe or showed multiple bites. Here as well, a mix-up can be excluded, even for the more intense outcomes. For an explanation, motivating factors such as target practice or object play needed to be considered. Both of these theories require further examination but are likely causes for the more severe bites.

Although "mistaken identity theory" can be ruled out as a potential cause for surfer bites by white sharks, there are other shark species that are involved with surfers, for example on the East coast of Florida where there are blacktips (*Carcharhinus limbatus*), silkies (*Carcharhinus falciformis*), spinner sharks (*Carcharhinus brevipinna*) and possibly even bull sharks (*Carcharhinus leucas*) [42]. The carcharhinid sharks' diet primarily consists of fish but not pinnipeds, and they do not even live near pinnipeds, thus the "mistaken identity theory" in shark incidents involving surfers along the Florida coast could not even be considered.

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The "mistaken identity theory" arose at a time when sharks were still thought of as having rather low intelligence and being primarily driven by their instincts. From that viewpoint, a mistake could make sense but even so, considering the rather long coevolution between the white sharks and pinnipeds, it is difficult to accept that these sharks could be misled, since a surfer looks rather dissimilar to the outline of a pinniped when seen from below. But even if any silhouette resemblance could be established, a shark would have to be pretty much right below the surfer when looking up, because the shallower the approach angle the less likely the silhouette will fit the outline of a pinniped. It is a fact that most surfers are indeed bitten in rather shallow water that would not even allow a shark to swim straight up from directly below once it notices the surfer.

The phenomenon of sharks biting surfers needs further examination, not just from a species viewpoint, like the carcharhinid sharks, but also from a viewpoint of the approach angle. As we will see in the next section, sharks are able to understand human body orientation [10, 11], which leads to an interesting question; can white sharks and carcharhinid sharks determine the orientation of surfers when sitting or lying on their boards?

1.3. Understanding human body orientation

Whenever people recall an incident with a shark or just a sighting, they use their own body orientation as a reference for the shark's approach direction, i.e., the shark came from behind [43–45]. Although it is commonly accepted that a person's body orientation could be used to explain a shark's approach direction, whether sharks are indeed able to understand such orientation has never been questioned [10, 12].

People have been intensively using the ocean's shorelines for fishing and harvesting purposes for only a few hundred years, making it very unlikely for even shore-oriented shark species to have learned human body orientation. Not having coevolved seems to make it rather unlikely that sharks would be able to understand a person's body direction. However, our research showed that this is not true. Sharks, in this case Caribbean reef sharks, *Carcharhinus perezi*, are able to do just that [10], and it is highly likely that direction of an approaching shark is thus influenced by the person's body orientation [11]. We were also able to show that when changing our body position from horizontal to vertical, e.g., standing up in a shallow area, that bull sharks stayed significantly farther away than when the test subject was lying flat at the same spot. This raises the question of what these sharks focus on to determine human body orientation, and what causes a reaction in them when changing a human's body position. It is known that different species of mammals can identify human body and face orientation [46–48] and are even able to follow a person's gaze and eye movements [47, 49]. It needs to be determined whether sharks are also able to make such detailed observations. However, considering that a swim pattern determination of a shark in the vicinity of a person can take place beyond the close visual range, other factors are likely to come into play. Although there remains much to be understood when it comes to shark-human interactions, the shark's vision must play a crucial role. We also observed that once eye contact was interrupted during an encounter, e.g., by lifting a camera in front of the person's face, that sharks veered away. Whatever it is, sharks seem to react to human eye contact, but there must be something else when the shark

is close to the visual range. Of course, one could argue that human locomotion or the direction a person is moving is the trigger of such decision-making and has nothing to with a person's visual system. Should the visibility be low, a shark could indeed follow whirls generated in the water by a person's feet or hands. Thus, the recognition of the pure motion direction of a person seems more likely to give a shark a sense of a person's orientation in the water. But such an idea falls short when a person is not moving.

When sharks approach humans, they prefer to come up from behind [10]. But not just that, the larger the animals, the closer they seem to swim to the sea floor [12] should the person be close to it. We investigated the possibility that this may reflect some kind of stealth behavior. However, biting the person at the end of such an approach does not seem to be the purpose of stealth in this situation but is rather used so that the shark remains unseen, thus free to observe and learn in safety.

Results from our studies show that sharks do not have an intention to harm when approaching a person from behind; they do not have a mean streak, and their goal is not to sneak up and bite but take advantage of approaching the blind side of a person to remain unnoticed.

1.4. What do bite rates tell us?

The study of shark-human interactions does not only deal with the actual communication between sharks and humans in different scenarios but also endeavors to understand where and when bites occur [33, 50, 51].

Between 1994 and 2009, 546 shark bite incidents occurred along the coast of the continental United States (some incidents were excluded where direct provocation by the person triggered the bite, e.g., grabbing a shark). Around 2/3 of these incidents occurred in Florida (365 cases), followed by the Carolinas (83 cases) and California (50 cases).

Although there is a plethora of information on shark bites and the places where they occur, they often only reflect single events [52] or focus on bite numbers. The former often uses a more detailed forensic approach, which can be of great value (see later paragraph); the latter is often rather flawed since the absolute bite number is usually not put into its proper context. The obvious shortcoming of such numbers is that they cannot be easily compared, except for the actual difference since no connection is made to the numbers of people on the beach at the time. To overcome this shortcoming, we defined the term "bite rates," which reflects the ratio between the total annual bites for a certain region to the yearly estimated beach attendance for that region [33]. For our studies, the beach attendance data were taken from the estimates determined by the United States Lifesaving Association (USLA), a not-for-profit association of professional lifeguards. It is understood that these numbers represent the beach attendance, and not how many people were actually in the water at a given time, but the data were sufficient as a population proxy of people entering the water. Although beach attendance numbers are fairly well established, there are some areas for example in Florida where shorelines are not observed by lifeguards, and thus no numbers were available. In order to overcome such shortcomings, we approximated beach populations by using data from adjacent beaches where populations were known. We then applied a spatial scan statistical tool, called

SaTScan [53–55], classified each incident and assigned it to a specific area (a unit) within a county. Then, we analyzed the data in a three-dimensional and two-dimensional manner, with and without the aspect of time. The approach identified primary and secondary regional clusters, which showed significantly higher or lower bite rates than average.

The obvious advantage of bite rate measurements over total bite numbers is that we are able to accurately look for common denominators. This is especially helpful where high and low clusters are adjacent to each other.

The coast of Florida is well known as the region with the most bites annually, and this is especially pronounced on the shoreline of Volusia County, which is also labeled as the "shark attack capital of the world." However, despite the superlative label, the probability of getting bitten is still more than three times lower than for Charleston County in South Carolina [50].

Although different environmental factors come into play when shark bites are considered, we also have looked at more general phenomena, such as the cycle of the moon [56]. It has been suggested that lunar cycles play a role in influencing the number of bites; during the periods of the full and new moon, the number of bites would be increased. We compiled all the bite data from 2002 to 2011 and compared their occurrence with the respective lunar cycle. In order to illustrate any possible correlations more clearly, we used the number of bites on the very day of the full and new moon within the range of ±3 days of that date. The results clearly showed that there is no correlation between the number of reported shark bites and the stage of the lunar cycle. Does this mean that the lunar cycle and its influence on tides do not have an effect on the sharks? Not at all, but the effects are likely subtler, and our data only suggest that it is just not related to shark bite incidents. Although there is no obvious correlation between shark bites and lunar cycles, the question remains why people had the idea in the first place. There is more light during a full moon, thus it seems plausible that this could facilitate the interaction between a surfer or swimmer and a shark during nighttime hours, but the opposite would be true during the new moon phase, which then would need another explanation.

There are numerous factors that have been previously mentioned, which could increase a shark's curiosity, like the water's low visibility encouraging a shark to get closer, a person's struggling motion or fishing close to where people swim, to just name a few. Similar to the lunar cycle idea discussed above, it is prudent to look at each suggestion individually and make sure that the source of the information is legitimate.

Probably, the most obvious and simplest anthropogenic factor related to bites is the constantly increasing number of human settlements close to shorelines and thus greater numbers of people entering the water. Although increasing numbers of humans will tend to increase the number of incidents, the noise created could also have the opposite effect and repel the sharks. A reduction in incidents could also be triggered by other factors such as eutrophication [57, 58] or harmful algae blooms infecting and limiting the shark's food base. All these potential influences need to be thoroughly investigated in well-planned studies.

Factors attracting sharks to investigate a human may also imply a motivational change in the animal. Therefore, realizing what keeps a shark in a certain area or what lured it in is an

important area of study. In most cases, an attractant lowers the hesitation threshold in a shark, motivating it to come closer. This per se is not dangerous, but the situation could get out of hand should the person not pay enough attention or react in the wrong way.

1.5. Comparison of different shark species

Environmental influences facilitate the outcome of an interaction between sharks and humans, but so do biological ones. The latter could be related to, e.g., mating, where a shark sees a person as a potential competitor, migration routes [51], where sharks following fish schools which engulfs a swimmer or surfer, and so on. But there could also be the possibility that smaller sharks show up or remain in some shallower areas to avoid being hunted by larger sharks. Despite the rather obvious connection between a small shark and a shallow area, the general causation of a larger shark's presence cannot always be definitively pinpointed. Even more so, the species identification may not be possible, as is often the case along Florida's shores [42]. As we already mentioned above, there are probably four species of the genus *Carcharhinus* that are responsible for most of the incidents along Florida's east coast. Despite the fact that each species can clearly be identified in a proper setting, its general physique and coloration make it hard for everyone, should the animal not clearly be seen or then only for a fraction of a second. That is not only true for their general appearance but also for the wound patterns they cause. The only species that has a clearly distinct pattern of tooth imprints is the bull shark. But even for that species, a superficial bite from a smaller specimen is hard to distinguish from others. This uncertainty makes analysis of why the responsible sharks mill around in certain areas at particular times challenging because species-specific attributes cannot be used. A much clearer picture with regard to species identification can be gained along the Pacific coast, where most incidents are caused by white sharks, *Carcharodon carcharias* [51]. This is a well-studied species in these waters [59], and many of its biological traits, including hunting tactics, migration patterns and so on, are well known. These traits could explain the high and low incident clusters and so permit being proactive and closing beaches during times when the number of sharks is likely increased [51].

The more we know about sharks, their migration routes, their hunting and nursery grounds, the easier it is to predict where possible conflicts may happen.

1.6. On the most exposed human water activity

Our results clearly showed that of all water-based activities, surfing has the highest exposure to contact with sharks [33]. Several factors seem to underlie this observation. Probably, the most prominent factor is the duration surfers stay in the water compared to other beachgoers. However, their frequent close proximity to sandbars may also have an effect although this needs more research. The reason for surfing close to sandbars is obvious; however, the attraction for sharks to sandbars is less clear. Of course, there is the oxygen-enriched water, caused by the breaking of the waves, which would allow sharks to increase their oxygen intake while having to swim less, but it could also be because more plankton accumulates within these breakers, thus attracting more fish. Due to the low visibility in these zones, the chances are that a surfer who falls off his or her board or is paddling may startle a close by shark, resulting in a

possible bite. Examination of the wounds of surfers from the East coast of Florida for example shows that the wounds sustained are mostly superficial in nature, indicating exploration as the main underlying motivation, which is the same result as for our study of white sharks biting surfers in California and Oregon [7].

Conflicts between surfers and sharks certainly need to be examined with more scrutiny. One of the most intriguing questions is whether sharks, white sharks and *Carcharhinus* species alike, interpret a surfer to be an animate or inanimate object [7].

1.7. Reading bite wounds

Whenever a bite incident occurs, the best indication of a shark's motivation lies in the detailed analysis of the wound, since possible eyewitness accounts or even descriptions by the victims are often biased. Trying to understand a wound and its creation follows the general methods of forensic analysis [8, 9]. One of the most least appreciated facts is that a wound is not just caused by the shark itself but the motion of the person as well. Most incidents are caused by the shark's curiosity to get further information of what a human being could be. A rather gentle grabbing by the jaws is sufficient to give a shark plenty of information. But it is this low-pressure bite that allows a person to jerk away his or her arm, or leg, thus causing a secondary wound.

Exploration is by far the most often frequently observed motivation for shark bites, followed by stress/startling, competition and provocation. Further causes are object play, target practice or a combination of different motivations labeled as "pattern compensation" [7]. As it is indicated that a variety of mental states underlie these bites, ranging from curiosity to self-defense. However, there are two possible motivations for shark bites that have never been observed: hunger and striking back, the deliberate intention to harm a person.

As described, exploration is the most prominent motivation underlying shark bites. Although these wounds are mostly very superficial, due to the low jaw pressure applied, the secondary wounds, caused by the reaction of the victim, can be rather severe and even fatal, should for example an artery be nicked. One of the main flaws when talking about bite severity is to use the category of "fatal." This outcome is the only one that does not properly describe the physical damage a bite caused. Although a massive bite could happen that leads to the death of the victim, a less severe injury that severs an artery can have the same outcome. Where the first scenario uses a lot of bite strength, the second one can be caused by a rather superficial bite to an area where an artery lies close to the skin's surface. Care should be taken in bite analysis and reconstruction, because wounds are not always what they appear to be, and this is especially true where surfers and sharks are involved. A bite can be caused through exploration which appears to be the case in at least two-thirds of all incidents [7]. Such a motivation might not be apparent in the case of a more intense wound, which could be caused, for example, when the lower teeth get stuck in the underside of the board, and the shark causes further damage as it tries to free itself.

Although we are starting to get a clearer picture why shark bites happen, some cases lack any obvious causative factors and seem to be a fluke of nature, despite that an incident is always caused by several factors what is also called "constellation of factors" [7].

Although the factors that cause bites are not yet fully known, we are starting to get a more complete picture. This raises the question why prevention of incidents, based on this emerging picture, is still in its infancy despite this knowledge, and the only solutions for beach protection seem to remain shark nets and drum lines, which are harmful to the sharks and other marine life [60, 61]. One problem is that there is a severe lack of awareness of which areas should be avoided for any water sport activity. To a nontrained eye, one beach may look like any other beach but that is far from true. Each beach is a unique environment, and some will be more attractive to sharks than others. But as just mentioned above, it is the "constellation of factors" that is crucial. A beach in itself may not cause a problem but should there be a fishing pier close by, it becomes a very different story. Fishermen indirectly attract sharks, and so anybody who swims down current of the pier can be put in danger. Whenever a fisherman hooks a fish, it likely releases stress hormones to warn others, as well as feces and body fluids. These components are then carried away with the current; the more concentrated the initial scent, the farther it can be picked up by sharks, as long as there is sufficient current. To the shark, using a search image, the scent represents a struggling fish, thus it looks for the origin of the scent and while doing so, it may cross paths with a beachgoer. Although the shark understands that the person is not a fish, it may still be interpreted as the source of the scent. Should the person also splash around and the emitted frequencies be similar to a struggling fish, the shark's interest could be more than just peaked. This potential scenario could play out quite often along Florida's beaches, where fishing piers are very common. The fact that more incidents do not occur, despite this constellation of factors is likely due to the sharks rather high threshold to approach an unfamiliar object. To avoid or at least reduce the likelihood of such a scenario, one of at least two regulations should be implemented. First, swimming should only be allowed up current of an active fishing pier, or second, the hours of fishing from a pier should be limited to early morning and late afternoon hours. Whatever restriction is chosen does not really matter as long as the two activities, fishing and swimming, are strictly separated.

1.8. Twist, wiggle, and the lowering of the pectoral fins

An understanding of the body language of sharks would enable improved outcomes in shark-human interactions. For example, probably the best-known aspect of a shark's expression of discomfort, when in the vicinity of a human being, is the lowering of its pectoral fins and hunching, the arching of its back [2]. However, this rather distinctive form of posturing has never been properly investigated. The lowered pectoral fins are most likely wrongfully misinterpreted as an expression of a threat. The likely cause seems to be the opposite; a shark feels threatened by the presence of the person. It is uniformly accepted that, whenever a shark lowers its pectorals, it does so in close vicinity of the person, mostly close to its "inner circle" [12] but never farther away. Should a shark feel the need to threaten a person, for whatever reason, it could also do so when farther away. However, that never seems to be the case. The phenomenon of lowering pectoral fins can be looked at in two ways: first, the lowering motion itself, and second, the final position of lowered pectoral fins. We observed on many occasions that the lowering motion comes into play when the shark needs to pivot or turn close to a person in a tight space. In this case, it lowers its both pectoral fins very quickly

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and twists one of them in such a way that it can create a left or right turn but hardly ever a downward motion. Whenever the pectorals are used in such a way, it is always done very rapidly and is called a pectoral burst [2]. When the movement is done more slowly, it seems to help maneuvering by increasing the lateral surface of a turning shark. In both cases, the pectoral fins are used for steering. Although one could argue that the movement still appears to express the displeasure of the moving shark, but the opposite still seems more plausible because it always moves the animal away from a person. A display that offers a very distinct advantage from a maneuvering viewpoint does not likely serve the purpose of a threatening display. Such a display would be conspicuous and goal oriented, directed toward the targeted object and not away from it.

Hunching on the other hand could have the assumed purpose of a threat display when directed against another shark, but this also has to be questioned when humans are targeted. Whenever divers seem to see this display, it is most likely caused by sharksuckers, *Echeneis naucrates*, attached to a shark's body irritating its sensory organs. One of these sharksucker-induced behaviors called wiggling [23] looks very similar to the initial posturing, identified by Johnson and Nelson [62] that was then declared as a threat display. Since sharksuckers are very commonly associated with sharks [23–25], it can be assumed that persons being witnessing these patterns may very well misinterpret what they see. However, the actual threat display described by Johnson and Nelson [62] with grey reef sharks, *Carcharhinus amblyrhynchos*, on this one occasion, has never been scientifically mentioned again in another setting or with another species. This seems rather odd, considering the number of people that encounter sharks in a variety of circumstances and surroundings, such as the tight spaces within reefs that seem to have facilitated the original description [62]. Could it be that this description was indeed a misinterpretation, and that the posturing observed was merely a fluke of nature? We cannot say for sure, but considering the frequency of shark-human encounters, we should be able to observe this type of posturing more often. It is up to the reader to make a decision what this display truly means or what triggers it, but looking at the original work and the two accompanying pictures reveal that in both cases, sharksuckers were attached to the pelvic areas of the shark [62].

We have shown in our previous studies that sharksuckers trigger a variety of effects [23–25], which have a wide spectrum, from very subtle to rather grotesque. Should a shark try to chafe the sharksucker off on the sea bottom [63], the meaning is rather obvious, but there is not always suitable bottom to do so, or the surface may not be close enough to jump out of the water and fall back with the targeted area first [64]. In such cases, the shark tries to get rid of a sharksucker by pushing or pulling the skin at the location of the attached teleost to loosen its suction, which can look rather intimidating considering the shark has to keep swimming to do this.

1.9. Yawning and other jaw gapes

The more complete the ethogram of sharks, the better the understanding of its presence close to a person. There is an obvious fascination in a shark's gape and its teeth, and this is at the forefront of many descriptions given when divers encounter them. One of the most memorable

displays is gaping of the jaw, commonly called yawning [24]. Although a true maintenance behavior, to an uninformed person it can look rather intimidating should a shark swim in their general direction, while performing this type of gape. Whenever a shark tries to gouge a piece out of a larger prey or carcass, its upper jaw is often everted. While doing so, a variety of muscles, tendons and ligaments, between this jaw and the connected brain capsule, are put to use. Due to the number and complexity of tendons and ligaments, the repositioning of the upper jaw into its resting position below the brain case can then be rather difficult, and not all the ligaments may be repositioned correctly again. Such misplacement seems to trigger this form of gaping, which often takes 10 times longer than a real bite [24]. The slowed down procedure is likely used to increase the chance of a correct placement. On rare occasions, the first gape, or yawn, is ineffective and the shark tries again by using a different speed.

In addition to this maintenance behavior, there is another type of gape that is occasionally seen among lemon sharks, *Negaprion brevirostris*, when lying on the sea bottom. In these cases, a shark opens its mouth as a signal to get cleaned between its upper teeth by sharksuckers [25]. This symbiosis has an ancient evolutionary history and was probably initiated back in the Eocene-Oligocene period, when sharksuckers first appeared [65, 66]. The interesting part of this cleaner-client relationship is that both the sharksucker and the shark can initiate a cleaning bout. The shark either opens its mouth and awaits a sharksucker, or the sharksucker swims up and down in front of the shark's eye in a dance-like manner to trigger a response, or can use a tactile response for the same reason. For a shark to be aware that food is stuck between its teeth, a sensory mechanism needs to be in place. However, it is unknown how this may work.

Likewise, it is not yet understood why sharks need to have their upper teeth cleaned at all, considering that they continually replace their teeth every 1–4 or 5 weeks [67–69]. Assuming that food resting between the teeth starts to rot, and that a broken tooth exposes blood vessels, the possibility of infection could then justify cleaning.

1.10. Shark-human interactions: a tool for shark conservation

The previous sections reflect either new explanations for old assumptions (e.g., that sharks do not have a threatening posture in front of humans) or explain commonly seen behavioral patterns of sharks (e.g., that pectoral fin lowering is used for a change of direction or increased maneuverability). In any case, the results facilitate the better understanding of the behavior of sharks in the vicinity of humans.

Shark behavioral patterns can be triggered by a multiple of triggers, such as human presence, nonhuman irritations, low visibility and others. Whenever explaining shark behavior, it is crucial to always describe the circumstances in which the behavior occurs and to highlight its role within the context of shark-human interactions. Each piece of knowledge helps to complete the picture we have of sharks. The better we understand these animals, how they function and what triggers an action or a reaction, the more fruitful our interaction with them as a species will ultimately be.

Although people feel afraid of a shark in front of them, they are actually just projecting their numerous fears into the animal; thus, a better understanding of the underlying meaning and

influences of certain shark behaviors will help to keep a person calm. Human fear among sharks comes from a lack of understanding of the situation, how it develops and most importantly what to do should a reaction be necessary. Therefore, it is of critical importance to "get to know" sharks and that includes being among them. Although science teaches us various techniques and procedures when dealing with different kinds of animals, one should always take time to observe them and let situations take place. "Getting to know" a shark or "getting a feeling" for them is crucial.

We are at a point in our research where we can offer answers to many shark-related behavioral questions, helping to create a far different animal to the one portrayed in JAWS. As already mentioned, it is an old adage that people do not protect what they are afraid of, thus by showing how sharks truly are and understanding how they behave, we may be able to raise the kind of awareness that leads to long-lasting protection of sharks and reduced incidents in which humans are harmed. Such protection is paramount if we want to save our oceans.

1.11. Future research in shark-human interactions

The examples in this chapter show how experimental approaches are uncovering the different aspects of shark-human interactions. This chapter also shows how all this information together can support the same goal: to better understand sharks. Some shark species have been brought to the brink of extinction largely due to human ignorance and the fact that people did not care enough about them due to the bad reputation these creatures had. Attitudes need to be changed on a worldwide level and that can only be accomplished by making sharks better understood. Although we are currently tackling a variety of questions within the experimental shark-human interaction field, some areas are still largely untouched.

Sharks are the most unknown and still the most abundant large predators in our oceans. Their presence in the marine realm demands that we get to know them better before it is too late. Any research helps, but the studies most able to change people's attitude and perception about sharks are those focusing on aspects of shark-human interactions.

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