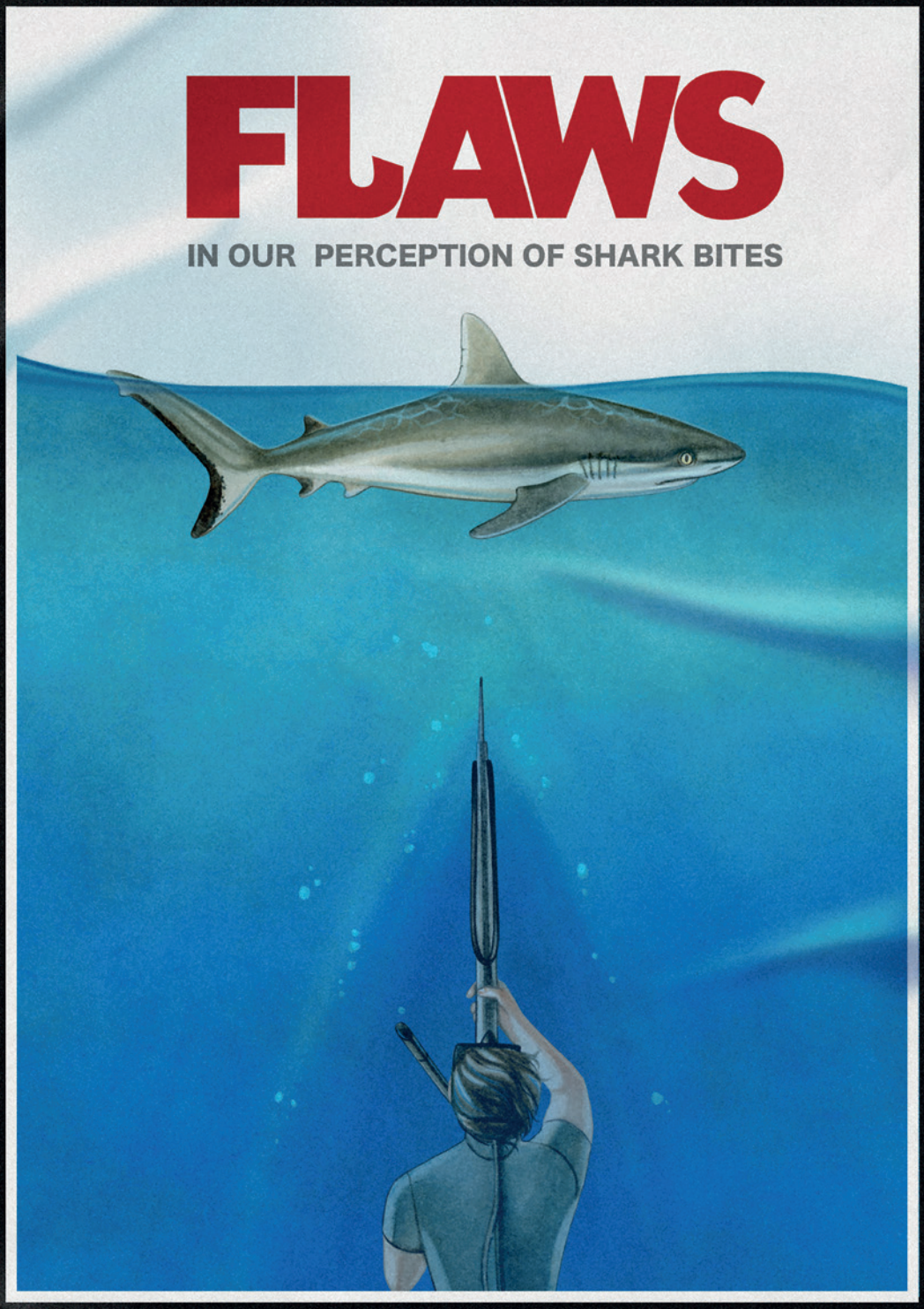

MARGAUX HUELVAN

ILLUSTRATING THE MOTIVATIONS BEHIND SHARK BITES AND SPECIES-SPECIFIC BITE CHARACTERISTICS

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ZUYD

FLAWS IN OUR PERCEPTION OF SHARK BITES

Illustrating the Motivations Behind Shark Bites and Species-Specific Bite Characteristics

by

Margaux Huelvan

A Thesis
presented for the degree of

Master of Arts in

SCIENTIFIC ILLUSTRATION

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Colophon

Cover illustration	Flaws, Margaux Huelvan
Coeditors	Rogier Trompert MA, Medical illustrator, Program Director, Teacher Master Scientific Illustration Zuyd University of Applied Sciences, Maastricht Institute of Arts, The Netherlands. Dirk Traufelder MA, Medical illustrator, Teacher Master Scientific Illustration Zuyd University of Applied Sciences, Maastricht Institute of Arts, The Netherlands. Dr. Andreas Herrler, apl. Professor (UK Aachen, RWTH), associate professor (FHML, Maastricht University), MSc (MHPE) Anatomie & Embryologie FHML Maastricht University, The Netherlands. Greet Mommen MA, Medical Illustrator, Advisor Master Scientific Illustration Zuyd University of Applied Sciences, Maastricht Institute of Arts, The Netherlands. Alexandra Vent MA, Medical illustrator, Teacher Master Scientific Illustration Zuyd University of Applied Sciences, Maastricht Institute of Arts, The Netherlands. Arno Lataster MSc, MEd, Clinical Anatomist, Biologist, Former Vice Head of the Department of Anatomy & Embryology FHML Maastricht University, The Netherlands.
External supervisor	Prof. Eric EG Clua, DMV, PhD, Senior Scientist, PSL Research University, Ecole Pratique des Hautes Etudes (EPHE) CRIOBE UAR3278, , University of Perpignan, France & Moorea.
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e-mail: huelvan.margaux@gmail.com
www.margauxhuelvan.com

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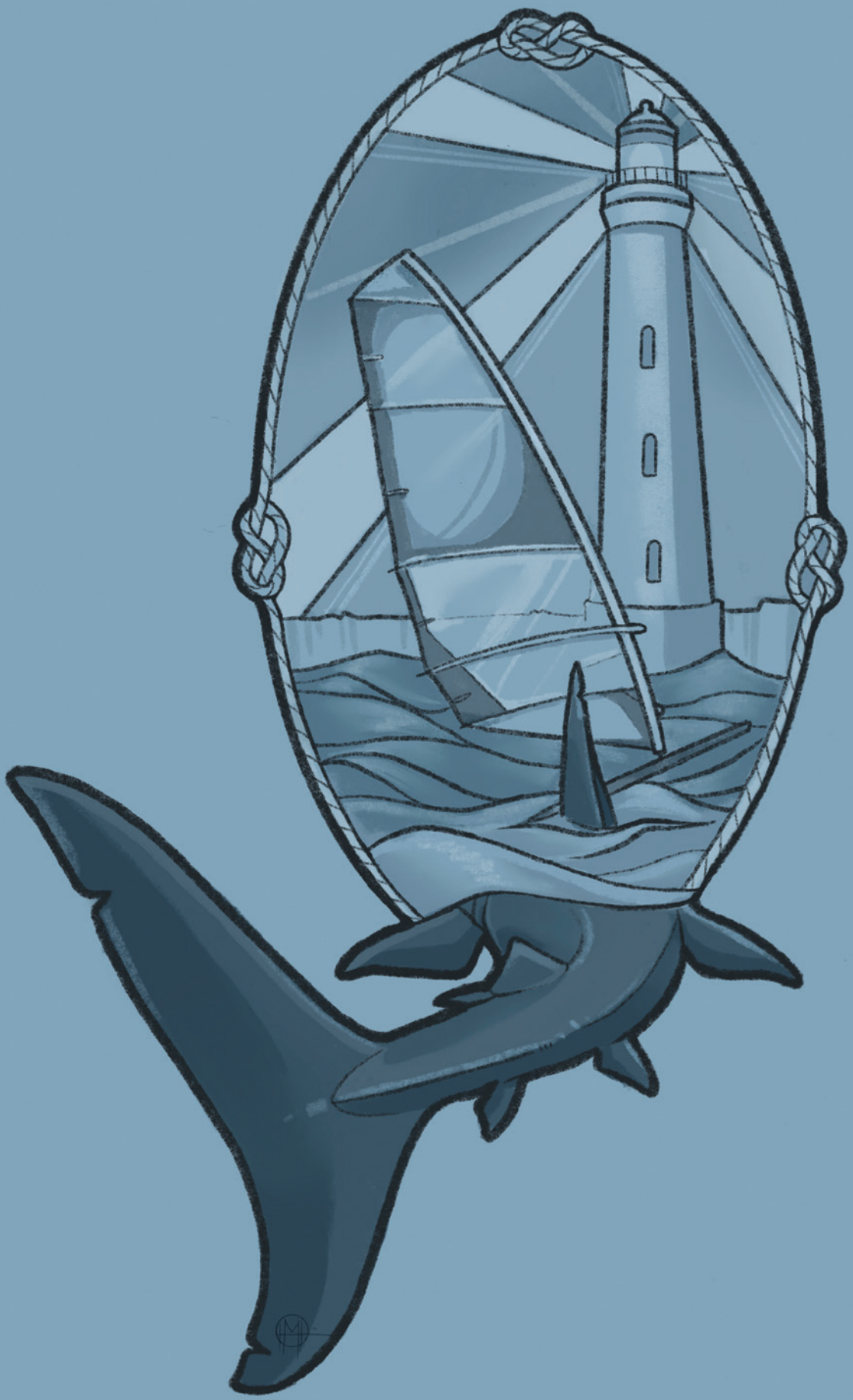


PREFACE

Marine biology has been a centre of interest to me. Growing up in a French coastal town bordering a marine protected area, I am familiar with the fishing industry and the importance of marine ecosystem health. Many of my relatives pursued careers and hobbies revolving around marine activities, shaping my interests from a young age. My second home, Norway, also shares a strong fishing culture. Safe to say, I grew up eating a lot of fish.

I share my father's love for the sea; when I was young, I would fall asleep to him reading me Jules Verne's *2000 Leagues Under the Sea*. As I grew older, I followed his passion for surfing. Surf culture heavily influenced my artistic style; bold graphic linework mixed with the realism of nature were what I gravitated towards in my illustrations. I would find myself illustrating sharks quite often, because frankly, how can a surfer avoid the topic of sharks?

My hometown's heavy focus on marine research meant a great aquarium was available for me to observe these animals. I remember their mural displaying shark attack locations, beside another one outlining the threats which humans impose on sharks. I believe my fascination for these animals lies in a mix of subconscious fear due to their negative reputation, and appreciation for their beauty. I often wonder how I would act if I encountered a shark under my board.

This thesis will take you through my process of illustrating the topic of shark bites. I will guide you through the steps and decisions I took to arrive at finalised illustrations, from artistic research to execution. My project will have reached its intentions if your view on shark bites is detached from the fear painted by pop culture and media.

INTRODUCTION

SHARKS, ECOSYSTEMS & HUMANS

According to the International Union for Conservation of Nature (IUCN), approximately 1,250 species of sharks and rays (*Chondrichthyes*) inhabit our planet's waters.[1] When one mentions sharks, their position as a top predator and danger to humans is assumed. In 2022, 57 shark incidents, of which 5 were fatal, were recorded in the International Shark Attack File (ISAF).[2] Hypocritically, an estimated 100 million sharks are killed yearly by humans.[3] The IUCN categorizes 32% of chondrichthyan species as threatened, with 40% still lacking evaluation.[1,4] Shark finning and bycatch stand as the biggest threats to these animals.[3] In regions where bite incidents are common, culling approaches to regulate shark populations pose an additional threat to species.[5]

Figure 1. Blacktip reef shark watercolor illustration.

The decline of shark species is not without consequences. Being apex predators, sharks uphold an important role in balancing ecosystem health. For example, sharks regulate coral reef health; various herbivorous fish feed on microalgae keeping blooms low for coral growth. Sharks maintain the population of such fish by preying on fish higher up the food chain. Sharks also control marine habitat over-grazing by regulating the population and distribution of herbivorous marine animals.[6] Despite their integral role, our perception of sharks is mainly influenced by their status as predators. One can often come across statistics on what is more likely to kill you; more annual deaths occur due to elephants or dog bites, yet these animals are still not demonised in the same way as sharks.[7,8]

THE DEPICTION OF SHARKS THROUGHOUT HISTORY

Raising awareness and changing the public perception of sharks proves difficult when their negative association has been prominent throughout history. Dating back to the 8th century B.C., the earliest depictions in Western culture on pottery and mosaic shed light on the importance of sharks in Mediterranean fishery activities. Representations in ancient Greek history highlight sharks as mythical creatures, yet also take form as counts of shark attacks. Advances in understanding these animals alongside their danger to humans were first detailed by Aristotle (330 B.C.) and Pliny (79 C.E.). However, during the Middle Ages, the drive behind scientific observation was replaced by religion and superstition. In this era, the notion of sea monsters was rooted in the depiction of sharks.[9-11] The development of communication technology over time allowed more exposure to the general public; from naval battle survivor stories to publications of bite incidents in newspapers, sharks have accumulated a negative reputation through media.[11]

It would be naïve not to address the 1975 movie *Jaws* as one of the most influential pieces of media driving fearmongering. Peter Benchley, the author behind the scientifically inaccurate vengeful shark, regretted the drive in sport fishing that the blockbuster sparked.[12,13] From thrillers such as *The Shallows* (2016) to the *Sharknado* (2013) franchise, the portrayal of sharks often revolves around a villainous animal.[14,15] Even in animated movies such as *Finding Nemo* (2003) the shark is not portrayed in the same light as Simba in *The Lion King* (1994). Yet, both animals are apex predators with the latter causing more human deaths a year.[16-18] Of course, not all depictions of sharks follow this notion; in cultures such as Hawaiian, sharks are respected as protectors and reincarnations of passed family members.[19] However, it is true that historically the lack of understanding has branded sharks as vengeful man-killing animals.

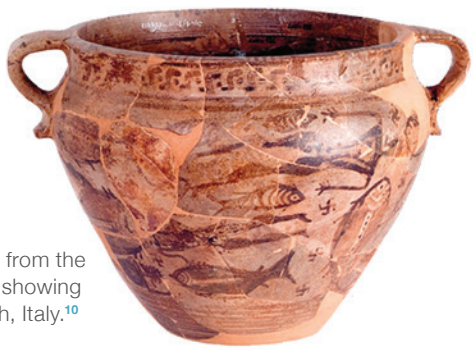


Figure 2. Pottery from the 8th century B.C., showing cartilagenous fish, Italy.[10]

HUMOUR OR REALISM?

During the second world war, the U.S. Navy was heavily implicated in pacific, warmer waters. Pilots feared crashing their planes into these waters only to encounter sharks. To subdue this fear, the U.S. Navy published the *Shark Sense* magazine where the odds of shark encounters and how to deal with them were addressed in comical cartoons. Although this magazine focused on humour, the messages conveyed were based on scientific understanding of shark behavior.[11, 20] *Shark Sense* is a good example of trivializing fear-driven associations; choosing a humorous tone is understandable in the context of alleviating the severity of going to war. However, the lack of realism in such depictions may be conflicting; important messages can be forgotten when the encountered shark does not resemble the illustrations. For this reason and the fact that my target audience differed greatly, I chose not to depict any of the scenarios in a comical way, focusing instead on realism.

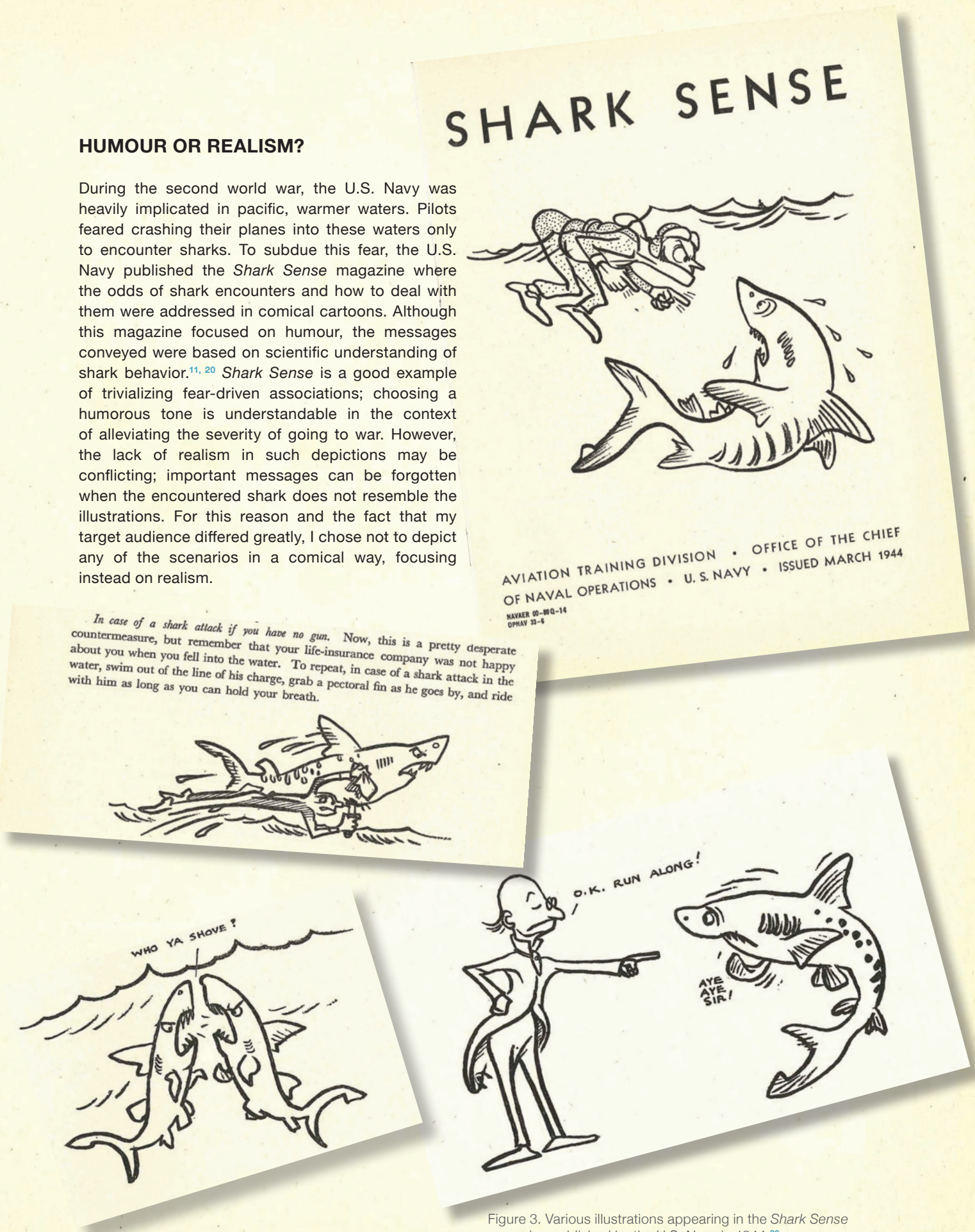


Figure 3. Various illustrations appearing in the *Shark Sense* magazine published by the U.S. Navy in 1944.[20]

RESEARCH INTO SHARK BEHAVIOUR

Knowing I wanted to illustrate a topic in shark biology, I began searching for my external advisor. I found the work of Professor Eric Clua, a veterinarian and marine biologist currently working on the Anti Shark Attack Project (ASAP). His work focuses on shark behaviour, specifically outlining 7 motivations for shark bites. Prof. Clua heavily advocates for the understanding that shark bites cannot be generalised to entire populations, and instead are usually linked to "problem animals" which are bold enough to bite. Therefore, reducing populations of sharks in blind-culling initiatives is inefficient as it does not specifically target the problem individual. Prof. Clua's research also centres around the forensic identification of these problem sharks, through patterns on bite wounds. The importance of DNA fingerprinting is also reflected in his work; shark DNA from a victim's wounds can identify problem individuals, allowing a more effective and ecologically important bite incident management strategy.[21]

Shark bites do happen yearly; for example, in February of 2023, New Caledonia enforced culling actions in response to a fatal incident.[22] A popular theory for the motivation behind a bite is that of mistaken identity. This states that a shark's poor vision leads to it mistaking a human (above, engaged in water sports) as natural prey's silhouette (i.e., a seal) (fig. 4). This is supported by research that found no differences when comparing the visual cues produced by seals and humans engaging in such activities.

Figure 4. The silhouettes of a seal, surfer, and swimmer from underneath.[23]

However, this research is a simulation and fails to analyse the multitude of other sensory organs a shark possesses.[23] It has also been found that bites on humans do not reflect patterns resulting from the hunting strategy that sharks employ on seals.[24] In this debated theory, Prof. Clua proposes the idea that the motivation may instead be an exploratory or predation bite, which will be discussed later.

USE FOR ILLUSTRATIONS

Around the time that Prof. Clua and I agreed on starting a project together, it was clear the illustrations were to be used for educational purposes within a chapter of his book, titled *The Singular Shark*. This was the ideal thesis project as it would require illustrations to be finalized for April. The main challenge discussed was to present sensitive images in a reader-friendly way, for a target audience of the general public and scientific experts. Following the requirements of my external advisor, I split my project into two main parts:

1. Illustrating the 7 motivations behind shark bites: Each of these 7 illustrations needed to depict the main elements from Prof. Clua's book chapter in one scenario, comprehensively and cohesively.

2. Illustrating the species-specific characteristics of bites: Tools, patterns and characteristics used for forensic identification of shark species and individuals were to be presented together in the style of an infographic.

With these parts set, I formulated the following research questions:

1. *How can I depict shark behaviour and bite wounds accurately without feeding into fear-driven associations?*

2. *How can scientific illustration be used to re-educate the general public on the misconception of the dangerous nature of all sharks?*

The purpose of this project is not to promote the removal of any blame on sharks in bite incidents. Instead, my goal is to research how to assist the education of the general public on shark behaviour, and shift views away from how this has been portrayed historically.

THE ROLE OF AN ILLUSTRATOR

"Why not use a photograph?" is a question which often surfaces in this professional field. In most cases, photographs contain irrelevant information. An illustration can condense, translate, and supplement information into a clear narrative. Illustrations can also allow a simpler fusion of multiple elements or process steps, in comparison to a series of photographs. Most importantly, illustrations allow for a portrayal of idealised and optimised elements, using the scientific illustrator's ability to convey how an average specimen or organism may appear.

In terms of this project, the role of an illustrator is important in various ways; the bite motivations outlined in Prof. Clua's chapter describe multiple elements leading to specific scenarios. With illustrations, these elements can be idealised and brought together in a way which would not be possible to capture in a photograph. As a scientific illustrator I am able to sculpt the narrative; first, I can include intangible elements (i.e., the thoughts of a shark or an invisible territory).

Second, I can remove any complexity such as troubled water, quick movements, detailed equipment etc. Above all, I am able to control how sharks are perceived in the illustration and regulate the "shock-factor" of bites and wounds. For example, this can be achieved avoiding the over-exaggeration of features (such as shark teeth), simplifying wounds, and reducing blood.

Idealising or "averaging" the appearance of bite wounds, while strongly emphasising species-specific characteristics and differences allows me to provide a functional and comparable overview for identification purposes. Simply providing multiple wound photographs together would have disadvantages; as these would most likely be on different regions of the body, a location-dependent bias could be a possibility. Depending on where the bite is located, variations in tissue thickness and fat distribution could cause the wound to appear differently. Additionally, omitting irrelevant elements which would be visible in photographs such as extra tissue scraps, blood, bruises etc., not only allows for a clearer visualisation of the bite but also reduces the sensitivity of the illustration for the audience.

RESEARCH & EXECUTION

CHOOSING A STYLE

To create a large volume of illustrations in my given window of time, I needed to employ a style that would benefit me with speed. Many of my past illustrations were created digitally with a graphical look. Here, I would apply strong and clean linework to allow the image to be deciphered immediately. Colours were easy to fill into linework and adding “cel shading” required minimal elaboration to render shapes recognisable. This shading technique consists of sharp shadow boundaries instead of a blended painted look (fig. 5).[25] Because of my familiarity with this style, its fast-paced workflow, and its visually comprehensive nature, I deemed this to be the perfect fit.

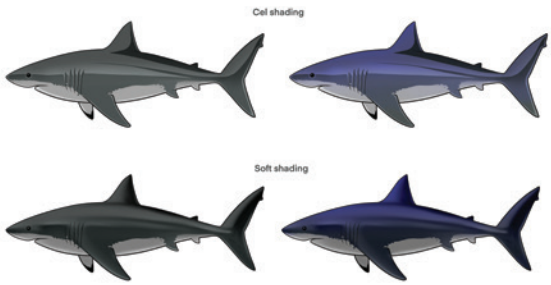


Figure 5. The technique of cel shading versus the soft shading style.

Regarding my decision to keep a realistic tone throughout my illustrations, I decided to push the graphical style to semi-realism; I would focus on depicting the true shape and characteristics of the subjects, while simplifying colours, shadows and outlines to ensure clarity. Graphical semi-realism would also benefit me in terms of underwater lighting; a blue hue over the colouring of a shark can converge into shaded areas making these difficult to distinguish, whereas bold shadow contours avoid this (fig. 5). Most importantly, being able to choose what to simply would provide a helpful tool to regulate the “shock factor”. Although a fully elaborated realistic painting style would fit this tone, complex shading and detail would provide extra information which could hinder the clarity of the message. Additionally, this would be much more time-consuming and therefore unfeasible within this project’s timeline.

LIGHTING & MODELS

Throughout history, artists have often used the convention of "top-left" lighting. Lighting from above provides a clear understanding of three-dimensionality; our perception of concave and convex structures is flipped when the light source is placed opposite from where one would assume natural light originates. Although it is unclear why the left is chosen for this convention, it may relate to how right-handed artists using window light avoided working in their own hand's shadow. Regardless, this convention allow for a comprehensive perception of images through consistency.[26,27] For this reason, I chose to show this lighting through my illustrations.

Sharks tend to share a general colouring termed "counter shading"; a dark dorsal region allows them to blend into the seafloor from any view above, whereas a lighter underside blends into water surfaces from views below.[28,29] I quickly discovered that under the lighting convention I was applying, tones would cancel out, making this colouring difficult to depict (fig. 6).

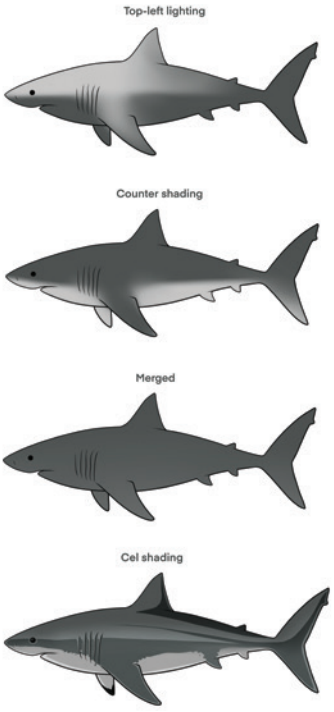


Figure 6. Top-left lighting, countershading and how to clearly show these together.

Luckily, this was solved by using cel shading, where hard shadow borders clearly juxtaposed any soft, base colour gradients. Within my process of creation, I required the use of pre-existing images as references. These were often limiting due to incorrect angles or lighting which did not match the convention I was applying. A great solution to this constraint is to generate models to cast on a light source from a desired angle. In a video lecture from Fernando Baptista, an illustrator for National Geographic, I learned how he creates polymer clay models for dynamic and realistic illustrations.[30] This also allows for more freedom in terms of viewing angles, where more immersive looks can be achieved.

I chose to use clay models in various instances during this project. Previously in my master's program, I dissected a spiny dogfish (*Squalus acanthias*) and built a model of this species to help with my coursework illustration. This species is bottom-dwelling and much smaller than the requiem sharks I was to illustrate, but their general shape remains similar. This model proved helpful for me as a base to incorporate the top-left lighting for many of the sharks in my illustrations (fig. 7).

Interestingly, clay also helped me illustrate organic shapes; In one illustration, I needed to depict a rocky background. I ripped pieces of clay and put them together to form an organic structure (fig. 8). In retrospect, rocks could have also served this purpose, but the clay helped reduce any bias the colouring of rocks would have on cast shadows.

To represent divers, I took the liberty to use my colleagues Susanne Stelwagen and Claudia Amort as reference images (fig. 9,10). I captured the photos myself using my iPhone. However, for many of the situations, I found that the idea of a dynamic illustration was beneficial for the overall message. A trick to capturing immersive images is to play with the perspective distortion a wide-angle camera lens offers. Luckily, my iPhone 13 had a great lens for this purpose. The difference is quite noticeable in the reference image taken with the standard lens compared to the wide-angle lens shown in figure 10.

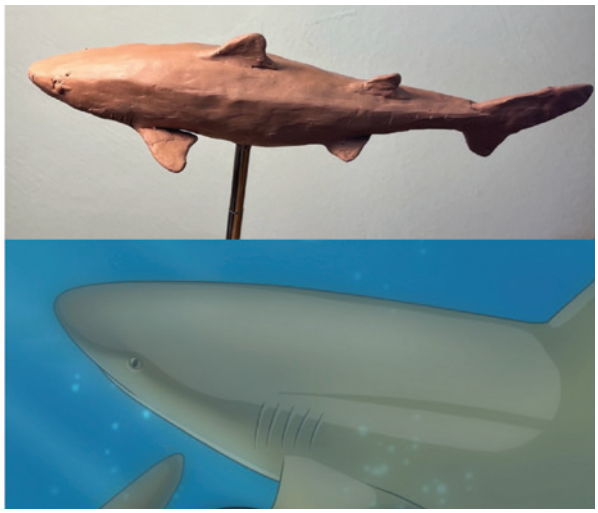


Figure 7. The clay model used for the lighting on most sharks illustrated in the cel shading style.

Figure 9. Claudia Amort as a reference for the defensive bite motivation scenario.

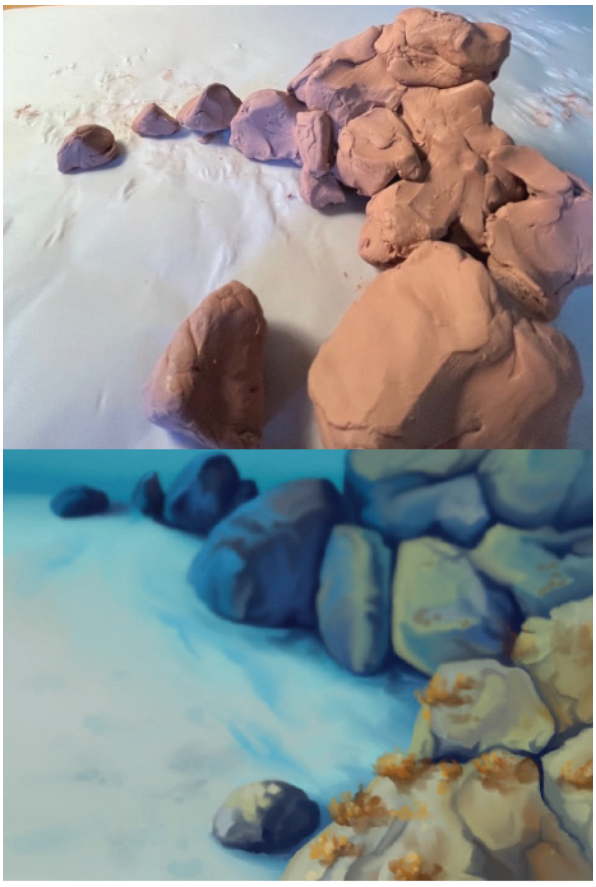


Figure 8. The clay model created for the underwater scene in the anti-predation motivation scenario.

Figure 10. a) An image of Susanne Stelwagen's arm taken from a standard iphone camera lens, and b) a wide angle lens.

GETTING TO KNOW THE SHARKS

My previous dogfish dissection allowed me to transfer my understanding of shark surface anatomy and musculature into this project (fig. 11). However, I needed to accurately convey the different characteristics of each species of shark. To do this, I studied each species through sketches, by using references available on Google Images, YouTube, and any informative websites. Analysing the differences in body shape, colour, patterns, eye size, fin shape and placement allowed me to transfer the specific look of a species into my illustrations.

From these sketches I created a series of watercolour paintings as shown in figure 13. To execute this, I created a blue underpainting; this allowed me to enhance the grey/brown tones of most sharks, but also create an underwater atmosphere from any blue reflection lights in lighter areas (fig. 12).

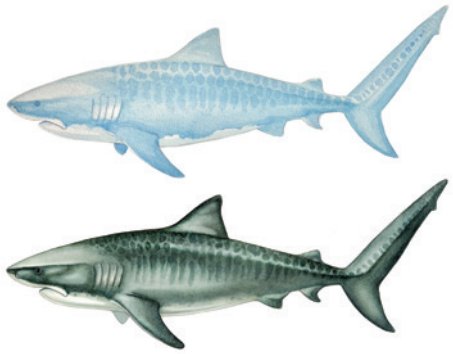
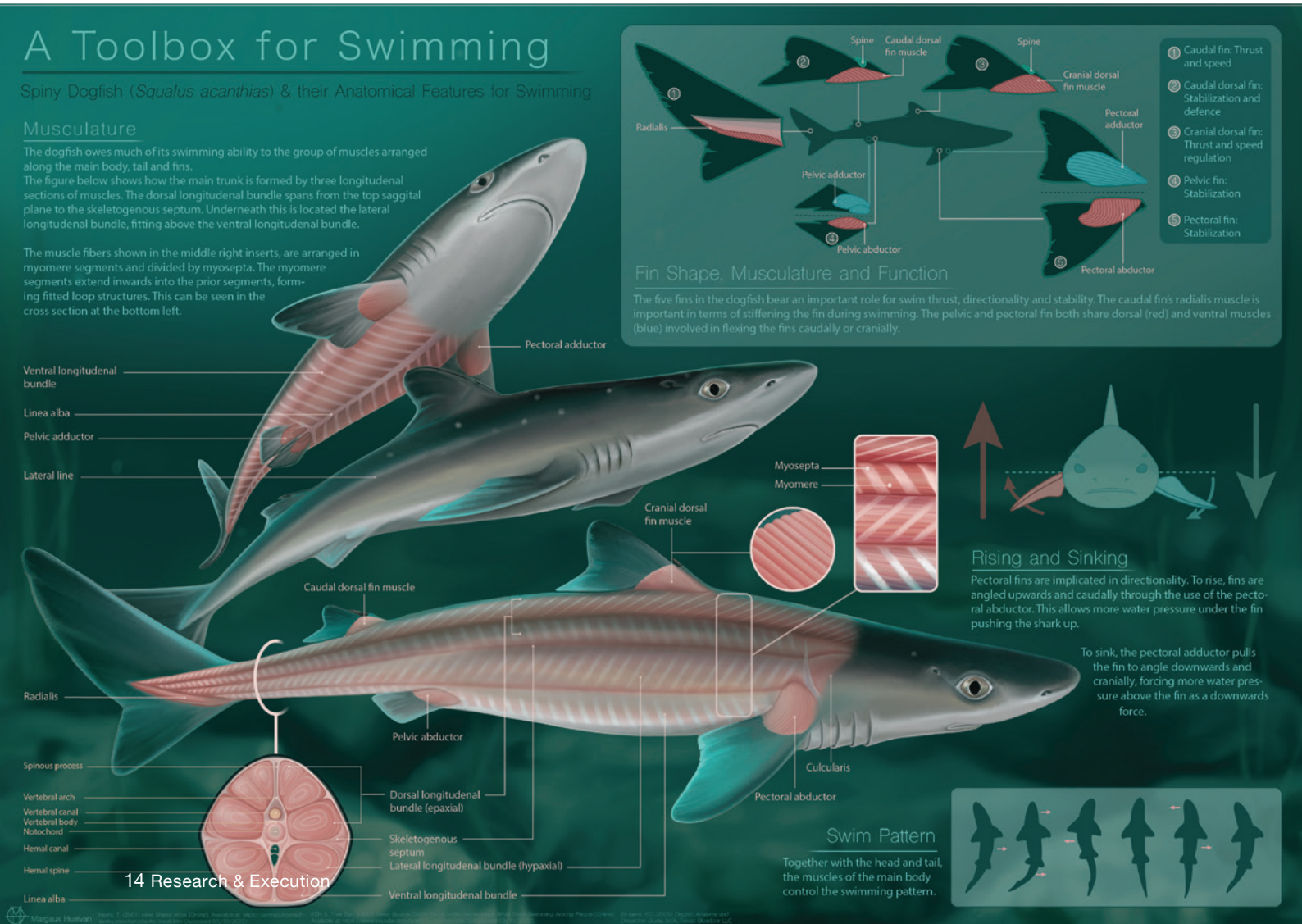


Figure 12. The blue watercolour underpainting (above), covered by the overpainting (below).

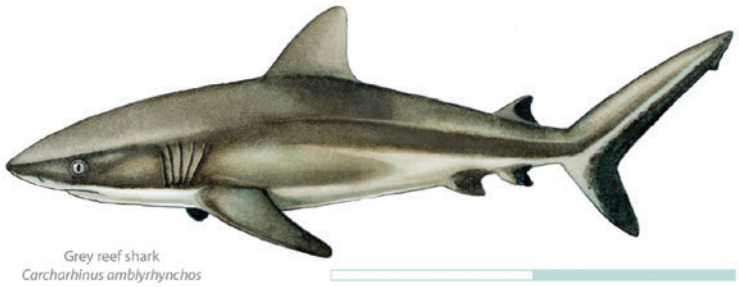
Shark musculature is arranged in bundles which are divided by one skeletogenous septum (fig. 11). This septum houses the lateral line, where movement-sensing cells are found.[29] This line is visually prominent; illustrating this helps carve the three-dimensionality of a shark from a simple ovoid shape.

Figure 11. Infographic on shark musculature I illustrated during my Master's program.



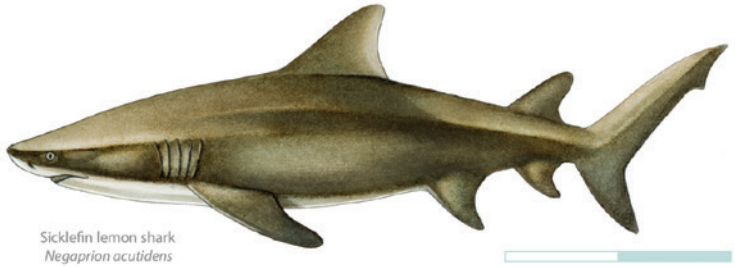
GREY REEF SHARK

These sharks are on average 1.8m long, with a grey or tan hue above a white underside. The edge of their caudal fin has a dark stripe. The rest of the fins are dark-tipped, except for the dorsal one. These sharks have large eyes and a round snout.[31,32]



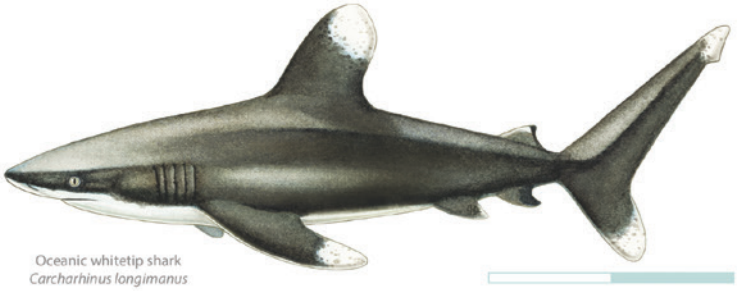
SICKLEFIN LEMON SHARK

These sharks are yellow-hued with a lighter underside and a black marking on their snout. This species has small eyes and crescent/sickle shaped fins with no markings. These sharks measure on average 3.2m.[33]



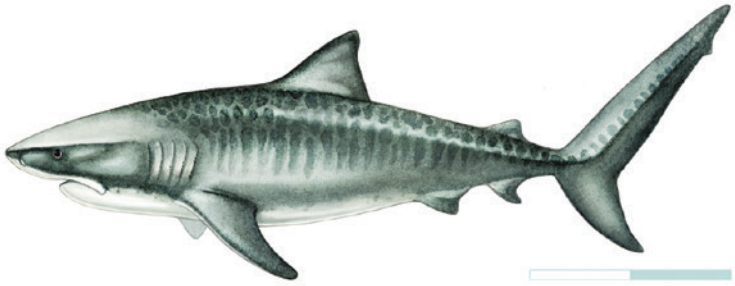
OCEANIC WHITETIP SHARK

These sharks have broad, rounded fins, with white patterned tips. Their colouring varies between brown, grey, to blue hues with a lighter underside. On average, sharks from this species measure 3m.[34]



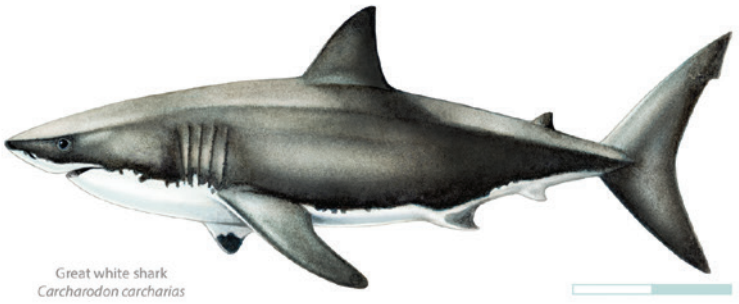
TIGER SHARK

Tiger sharks are large and reach 3-4m on average. These sharks have a grey to blue hue with characteristic dark stripes, spot markings and a white underside. Their snout is flat and wedge-shaped.[35]



GREAT WHITE SHARK

The great white shark has a blunt body shape, coloured grey with a white underside. The great white's tail is crescent-shaped and its snout is pointed. The average-sized shark measures 4.6m, although females are generally larger.[36,37]



BULL SHARK

The coloring of bull sharks is grey with a cream underside. These sharks reach approximately 3.4m. The snout of the bull shark is blunt and rounded. Their body shape is broad in the abdomen region.[38]

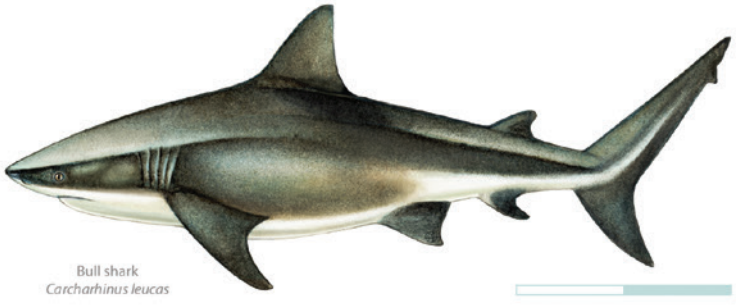
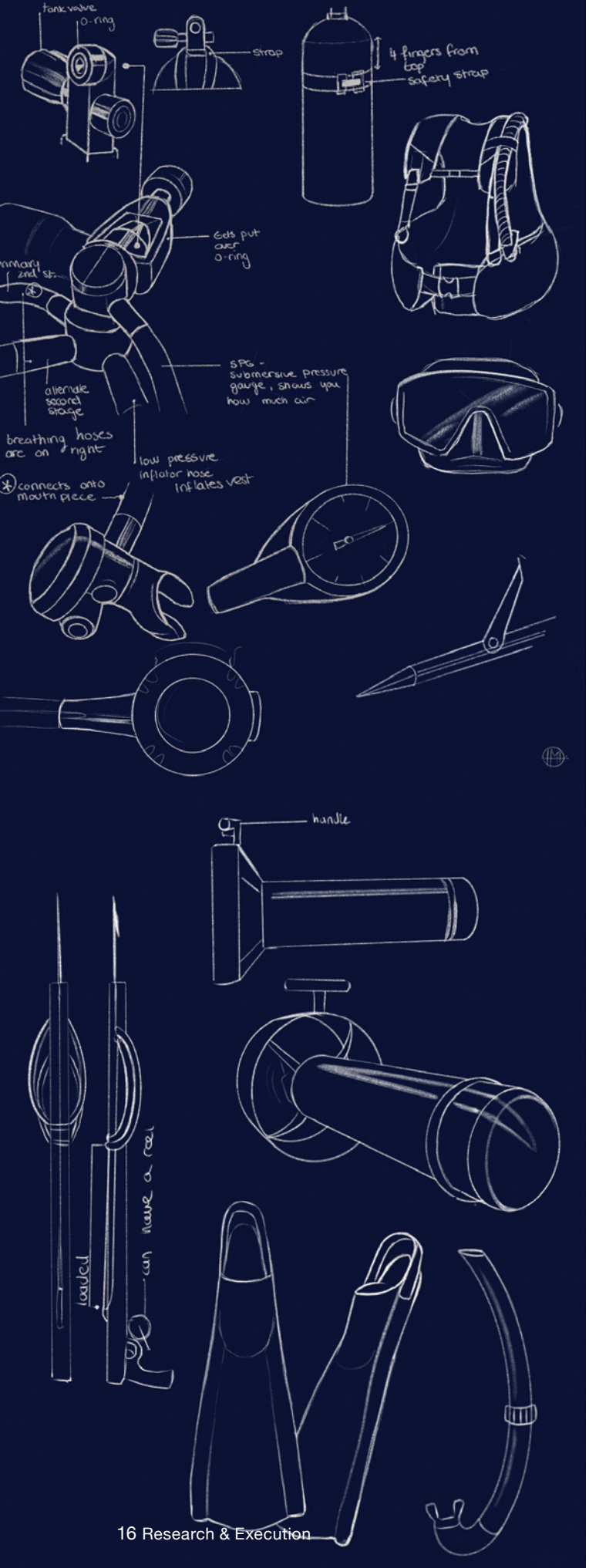


Figure 13. Watercolour illustrations of six various shark species. The scale bar represents 1m.



EQUIPMENT

Most underwater scenes for the bite motivations included a person engaging in an underwater activity. From freediving/snorkelling or scuba diving, to spearfishing and using underwater scooters, I needed to illustrate a variety of equipment. To research the complicated diving material, I viewed instructional scuba diving gear videos on YouTube. This allowed me to understand which part of the gear was essential to include, and what could be simplified or removed for clarity. With idealised versions created, I compiled these into a sketch document to use as a reference throughout this project (fig. 14).

APPROACH

A general workflow pipeline for both projects was applied (fig. 15). To explain this, I will use the example of the illustration I created for the anti-predation motivation.

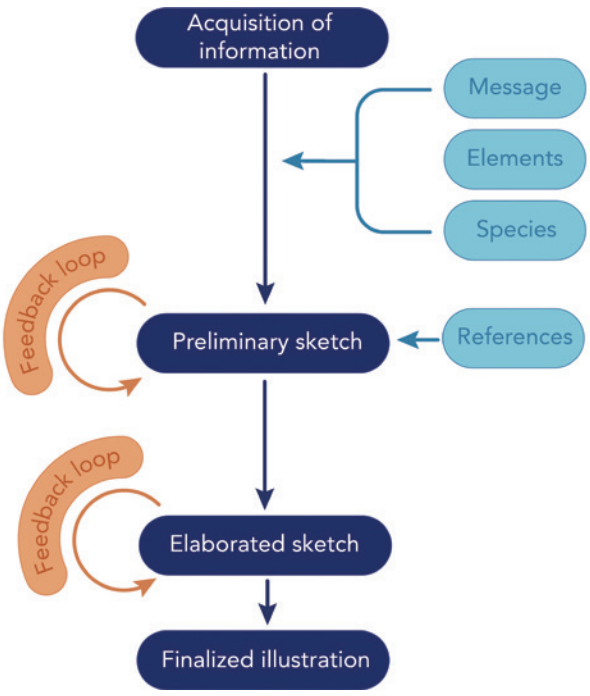


Figure 15 (above). Graphical representation of the workflow from initial research to finalised illustrations.

Figure 14 (left). Compiled sketches of every piece of equipment I needed to illustrate within the scenarios.

Figure 16. The anti-predation motivation.

The Anti-Predation Motivation: Some species such as the grey reef shark (*Carcharhinus amblyrhynchos*) have natural predators. A human's offensive actions can activate a shark's anti-predatory instincts; a diver approaching quickly (i.e., by scooter) to a close proximity, or trapping the shark in a place which cannot grant it an escape, can result in a bite motivated by fear.[39]

1. ACQUISITION OF INFORMATION

To accurately illustrate each topic, literature-based research was necessary. Prof. Clua provided many preliminary sources to start my research, including his book chapter. The benefit of the chapter was that the information for each motivation was presented in a literature review, condensed and clearly understandable. Although I used external sources for independent research, I chose to focus mostly on the information presented in the chapter for the first part of this project. This was so that my illustrations would reflect the detail presented in the text, to not over-complicate the scenario with irrelevant elements. However, the second part required the assimilation of information from various sources.

For each illustration, I needed to answer the following questions:

A) What message will the illustration convey?

After building this base of knowledge, I needed to condense each topic into one main message to convey through my illustration. For the first part of the project, this was to explain each bite scenario in terms of the shark and human's motives. For the second, the message was to define the characteristics of a species-specific bite.

The anti-predatory bite illustration needed to convey the notion that a shark feels threatened and trapped by a rapidly approaching diver, forcing the shark to act out of fear of predation.

B) What elements need to be included?

To deliver the main message, I needed to research which elements to include and how to depict these accurately. For example, to correctly illustrate a spearfisher, I needed to understand how a speargun functions. The elements' interactions with each other were also essential to evaluate; For instance, the species of speared fish had to be one that was present in the same geographical location as natural prey to the species of shark illustrated. I also needed to fit the correct background to the shark species' environment (i.e., open waters or coral reef).

A rapidly approaching diver on an underwater scooter, a shark and a rocky cove were elements required for the anti-predation scenario. The shark's threatened state would be shown in an "agonistic display" position, with lowered pectoral fins, a lifted head and arched back (fig. 17).[40] Bubble streams showing speed and a warning symbol would provide good visual cues for threat perception.

C) What shark species are present?

Aside the species-specific infographics, the chosen species reflected the ones described in the chapter's case studies. These needed to be illustrated correctly in terms of both appearance and behaviour. For example, grey reef sharks are faster and more aggressive compared to slow and cautious sicklefin lemon sharks. Therefore, I avoided illustrating the sicklefin in fast reactions.[32,33] Research articles, images and videos proved helpful to generate any reference sketches.

Figure 17. A screen capture from a video of a shark showing the characteristic display of aggression, also known as the agonistic display.[41]

It was challenging to find a reference photo of the grey reef shark in an agonistic display. Luckily, I was able to take a screen capture of a video showing this position to use as a reference (fig. 17).

2. PRELIMINARY SKETCH

Graphite sketches were used to explore the best composition of elements. Tools such as clay models and reference images were employed at this stage. Unless the sketch was already digitally created, it was scanned, cleaned, and coloured digitally using Procreate (fig. 18).

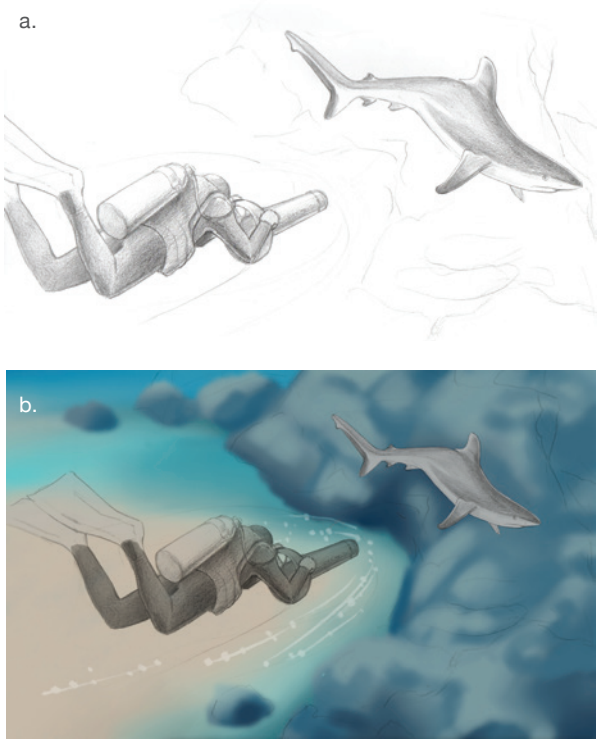


Figure 18. a) The scanned graphite sketch for the anti-predation motivation. b) The scanned sketch converted to the digital preliminary sketch.

A) Feedback loop 1

The sketch was sent off to Prof. Clua for feeback, where any changes were simple to make at this stage. Alterations were sent back for confirmation.

3. ELABORATED SKETCH

With an accepted preliminary sketch, the background was rendered first. This allowed me to immediately add depth to my sketch and I could arrange the elements in space to see what needed to be pushed back or forwards. From here, I was able to elaborate the elements in a global approach.

The workflow for this illustration was employed for the other 6 scenarios; to create an effect of underwater depth, the background was painted in a blurry realistic style (fig. 19). The graphite sketch was exported to Adobe Illustrator where the linework and flat fills were created. Adobe Photoshop was used to elaborate the flat fills and create the cel shading. To do this, a selection mask (pink) was applied to select the areas to be shaded. These would be altered in hue and saturation to create the shading, allowing a more dynamic feeling than simply pulling pixels towards white or black shades. The linework was then coloured to match the flat fills. Finally, elements such as symbols, bubbles, a gaussian blur and a blue hue were added to create the underwater scene.

A) Feedback Loop 2

The elaborated sketch was sent for another round of feedback.

4. FINALISED ILLUSTRATION

Any alterations were accommodated to generate the final illustration. Additional elements were also included such as textand symbols.

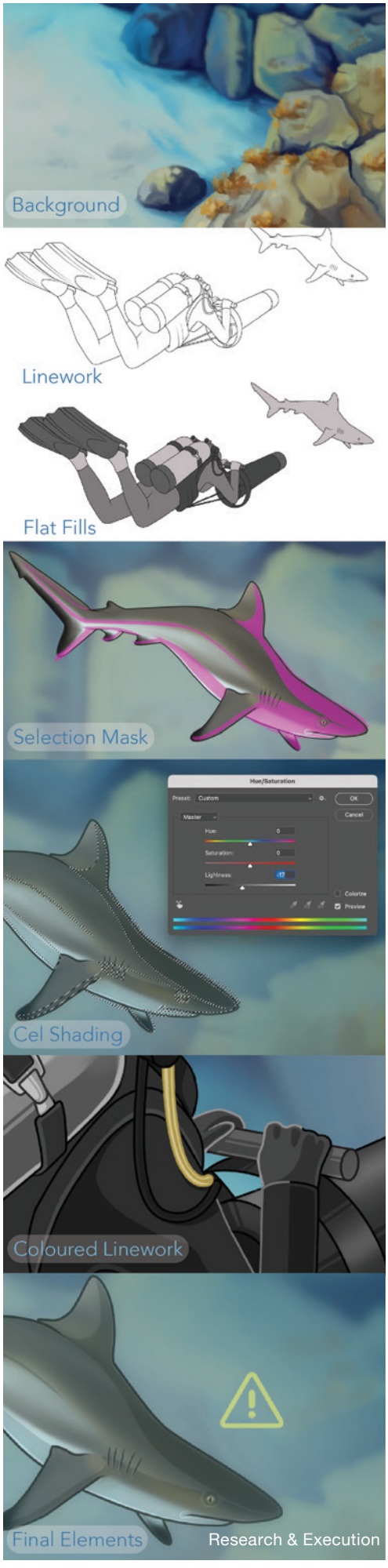
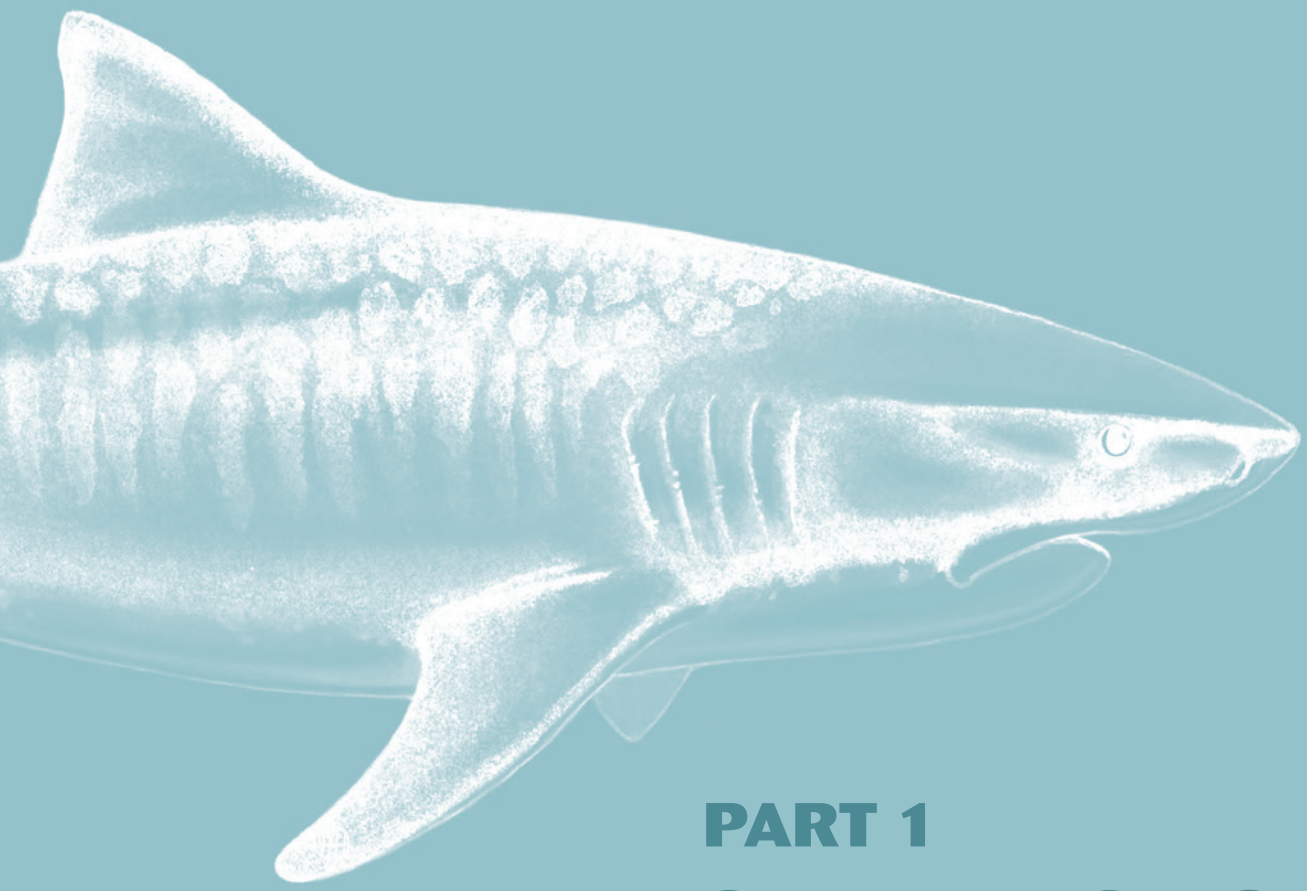
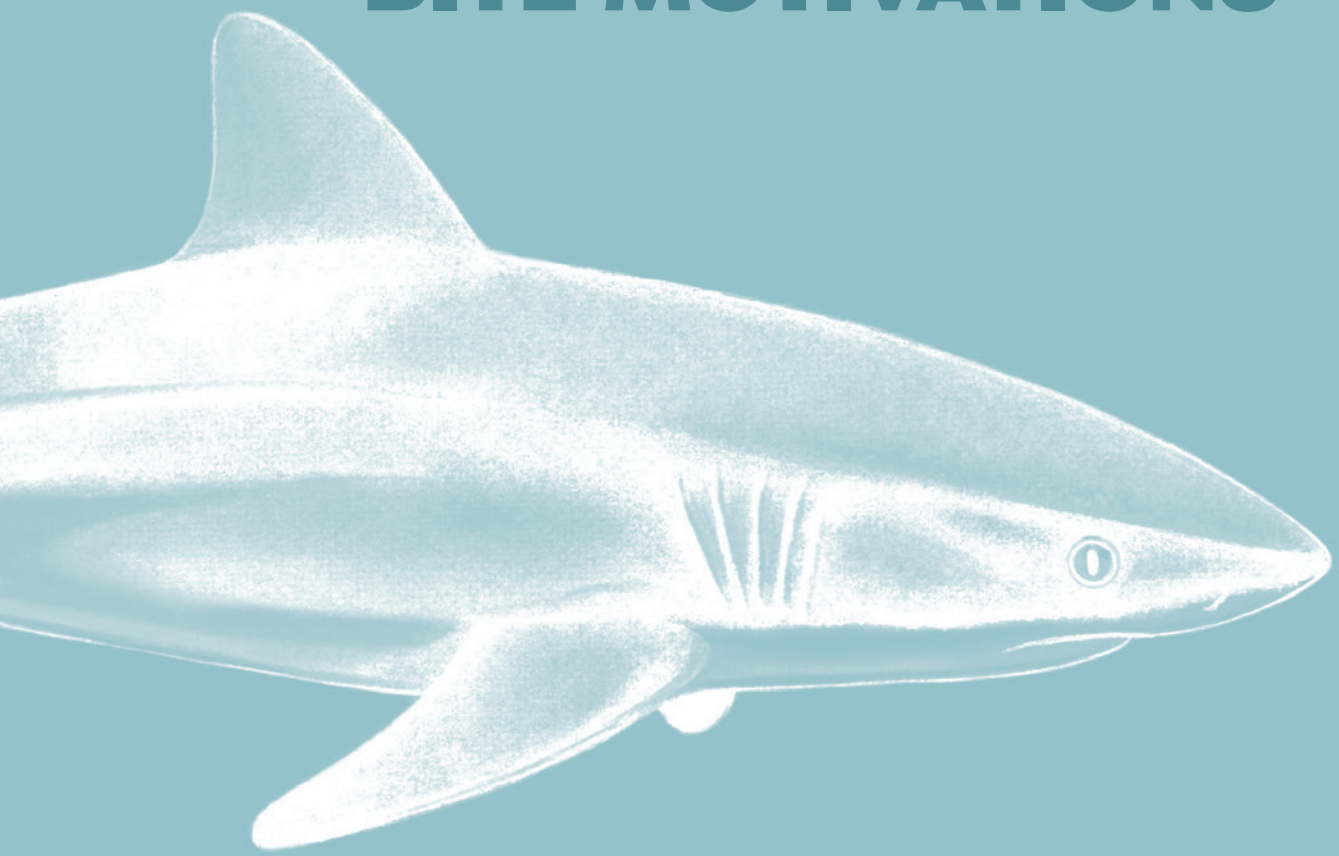


Figure 19 (right). The general workflow for the creation of the finalised illustration in the cel shaded style.



PART 1
BITE MOTIVATIONS



1. THE CLUMSY BITE

Mostly occurring in the context of shark feeding (artificial feeding in ecotourism to attract shy species), these bites happen on a feeder's arms when a shark cannot distinguish this from the food source. These accidental and spontaneous bites are not fatal and cause minimal tissue loss. The commotion and disturbance of multiple sharks in a feeding frenzy state can also drive this outcome.[39,42,43]

For this scenario, I chose to centre the focus on the diver's arm holding the food. I created a highly dynamic blurry background containing multiple swimming sharks to include the feeling of commotion. To show that this bite was accidental, I needed to make the arm difficult for the shark to differentiate from the fish. To further show the involuntariness of the bite, Prof. Clua and I discussed that a piece of fish from a previous bite could be added in the mouth of the shark, indicating a continuation of this intention.

In my preliminary sketch, it is evident I was reluctant to draw defined teeth to avoid the shark from looking too scary (fig. 20). This was not realistic and Prof. Clua's corrections were to show the teeth clearer and include a wound. I was also reluctant to illustrate this at first, but by including a glove on the diver I was able to avoid showing any broken tissue to dampen the shock-factor.

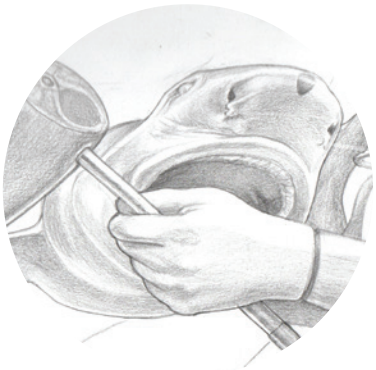


Figure 20 (above). The preliminary sketch showing less teeth.

Figure 21 (below). The clumsy bite motivation.

During feeding, sharks protect their eyes with opaque white nictitating membranes (fig. 22a).[44] Only this bite scenario depicted a situation in which this would be visible. In my opinion, the combination of prominent teeth and the lack of a pupil gave the shark an unsettling appearance (fig. 22b). I decided to decrease the membrane's opacity to show the pupil more. The effect of anthropomorphism is visible here; the addition of humanised traits such as a visible pupil increases the notion of familiarity in cases where these traits do not exist.[45]

Figure 22. a) The nictitating membrane.[46] b) The nictitating membrane on the clumsy bite illustration, with c) the pupil added back.

2. THE TERRITORIAL BITE

Like the anti-predation motivation, this scenario reflects a shark's response to a human's offensive actions. However, here the proximity of the human to the shark is the offending factor. Prof. Clua outlines how sharks possess an "idiosphere" area of territory, where any entry can be perceived as a territorial challenge. Contrary to the anti-predation situation, the shark looks to dominate and ward off the intruder (entering the idiosphere without an aggressive motive), instead of fleeing.[39]

With the territorial motivation, I was presented with artistic freedom to illustrate the non-tangible "idiosphere" however I felt fit. I used this to my advantage to differentiate which diver and shark were perceived as a threat by entering the idiosphere, and which were swimming by at a non-threatening distance. I executed this by using a glowing contour to highlight where the idiosphere was "pierced" for entry.

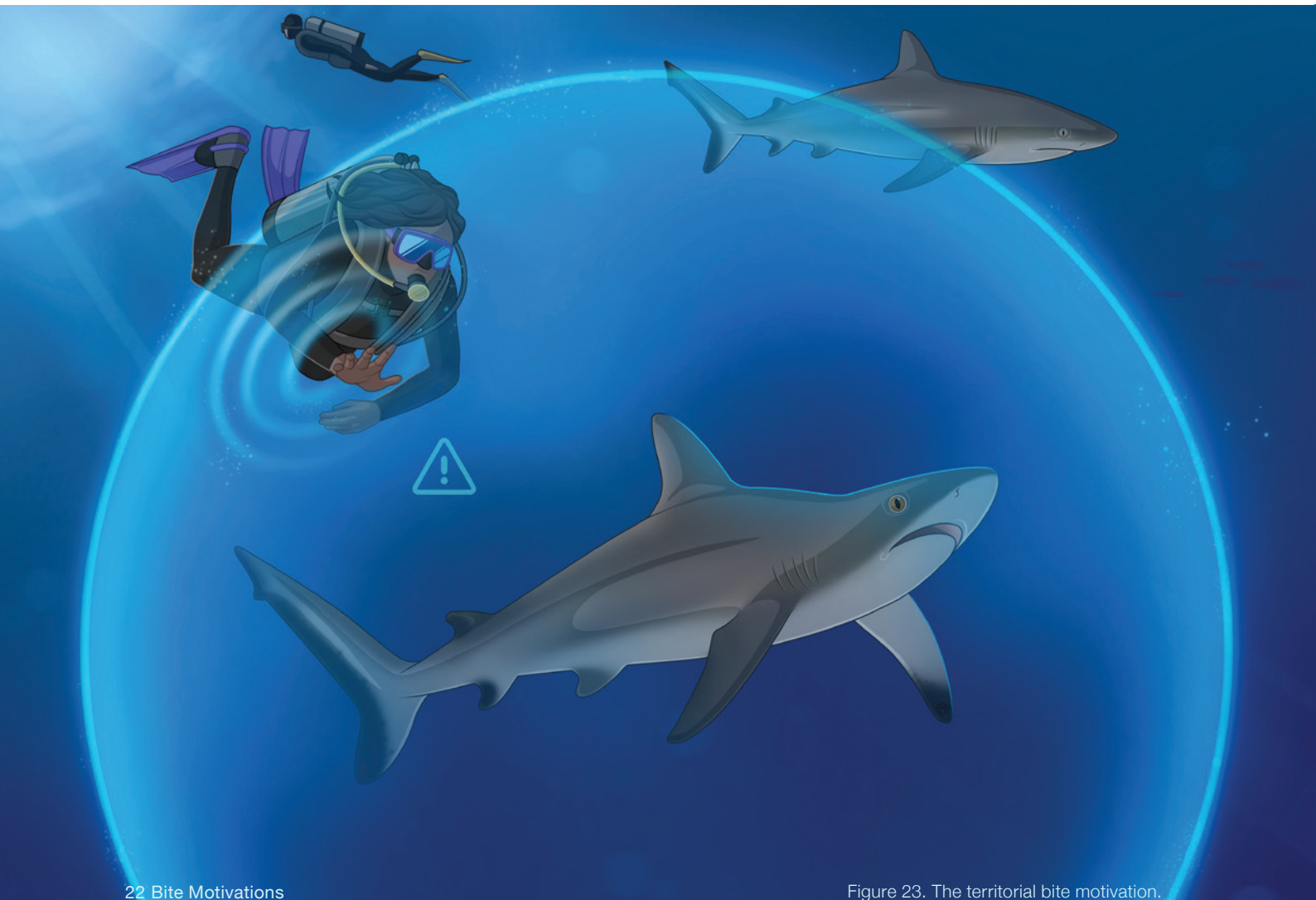


Figure 23. The territorial bite motivation.

3. THE COMPETITIVE BITE

Prof. Clua describes the driving factor for this motivation being the state of the shark; extreme hunger from scarce prey can drive a shark to pursue a fisherman's catch. When a fisherman is nearby trying to save their catch, a competitive powerplay may result. The shark's bite on any part of the body marks the difference between this and the clumsy motivation.[39]

Multiple sketches were created for this motivation; in the first one, the shark's motivation to bite the fisherman was unclear (fig. 24a). In the second, the shark was not approaching the diver (fig. 24b). The solution was to show the shark approaching the diver from below. Another difficulty was to avoid similarities to the clumsy bite. Therefore, the bite needed to be clearly aimed at the diver's free hand. This also allowed me to enlarge and highlight the fish as the main focus to emphasise how this scenario is food motivated.

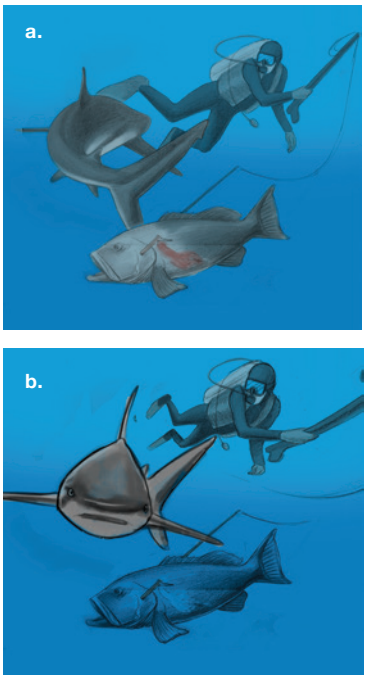


Figure 24. a) The first preliminary sketch and b) the second.

Figure 25. The competitive bite motivation.

For this illustration, I was faced with the task of representing a fish species which fit the following criteria: the species needed to be fished and consumed by humans, present in the same geographical region as prey for the grey reef shark, and visually striking to stand out as the focus in my illustration. After some research, I found the leopard coral grouper (fig. 26, 27) perfectly fit these three.[47]

4. The Defensive Bite

A shark may present a defensive bite as a result of a human's aggressive actions. For example, a spearfisher with catch may try to ward a shark off by spearing it. If the spearfisher restrains the fleeing shark with their speargun, the shark will be forced to act on its survival instinct and bite anything in close proximity. These quick bites can happen on any part of the body.[39]

Figure 26 (left). Leopard coral grouper.[48]

Figure 27. Habitat of the leopard coral grouper and the grey reef shark.[49,50]

Figure 28. The defensive bite motivation.

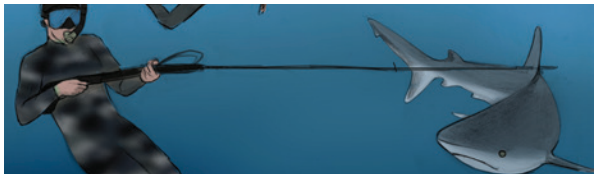


Figure 29 (left). Preliminary sketch showing the tension between the fired speargun and shark.

To ensure the defensive motivation was clearly understood, I needed to emphasise how the human was directly aggressing the shark. Initially, my sketch focused on the idea of the shark being restrained from fleeing with high tension in the speargun's fishing line (fig. 29). However, I chose instead to focus on the shark's retaliatory motives, showing a turning motion onto the fisherman (fig. 28). This would allow me to highlight how the second fisherman was not a perceived threat, or an interest, even in the presence of a fish.

5. The Exploratory Bite

Although related to feeding, this bite also reflects motives of curiosity and education. A shark must identify what it encounters, before deeming it suitable prey.[39,51] A growing shark will need to change its diet. Thus, the identification of potential prey is important for it to adapt its hunting strategy.[24]

A shark will use its senses and "bump" or bite to taste whether an "object" is alive, dangerous to pursue, and a good source of nutrients. Some animals (i.e., birds) are not fit as prey due to their low fat content. Humans are not the natural prey of sharks, therefore, the essence of this bite is that it is released, leading to superficial wounds without tissue loss.[39,51]

This motivation's main characteristic was the release of the bite and the retreat of the shark. Adding a blood trail was my initial idea to highlight the trajectory of the retreating shark, however, I deemed this unnecessarily dramatic. Graphical elements such as zooms and symbols proved a better alternative as they also allowed me to visualise the shark's decision-making process; a human would represent an inappropriate food source and danger to the shark. I also chose to display the diver in a short wetsuit to visualise the bite clearly.

Figure 30. The exploratory bite motivation.

Figure 31. The predatory bite motivation.

6. THE PREDATORY BITE

Although this bite is the least common, it is the most feared. For this bite to occur, the following conditions must be met; a shark must be hungry enough to fulfil an exploratory bite to the goal of predation and possess a bold enough personality to hunt a human. These are referred to as “problem sharks”. These bites can be repeated, fatal, with a significant amount of tissue loss. A human is at an unfortunate place and time, encountering the wrong shark.[39,51]

Since many victims of this motivation are seen engaging in watersports, I chose to illustrate a surfer. To avoid any associations with the mistaken identity theory, I chose not to illustrate the surfer as a silhouette from the underwater perspective of the shark. I wanted to evoke the notion that the fault does not lie with the actions of the human, as shark is purely motivated by feeding.

My preliminary sketch for this motivation was that of a surfer sitting on her board unaware of the approaching problem shark underneath (fig. 32). However, it was discussed that this would not allow any distinction from the exploratory motivation. Therefore, the bite would have to be already completed. Including a surfer reaching out of the water allowed me to use splashes to convey panic and fear.

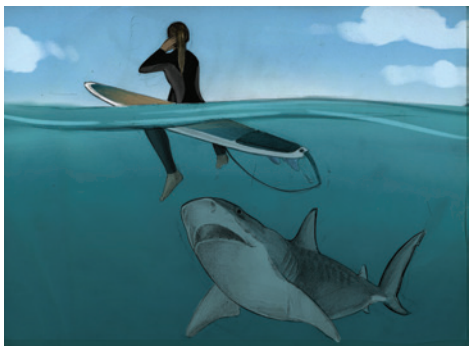


Figure 32. Preliminary sketch with the shark approaching the unaware surfer.

Multiple sketches were created with varying severity of wounds. The final agreed version showed a substantial loss of tissue to distinguish this bite from the exploratory motivation (fig. 33).

The original illustration was also flipped; this allowed the shark to appear as if it were rising to repeat the bite, instead of backing away/sinking as seen in an exploratory bite. This effect owes itself to the principle of left-to-right alignment; arranging objects to match the reading direction allows a sense of a beginning and ending (although this is mostly applicable to western reading directions).[52] An example of this can be seen with *The Elevation of the Cross* by Rubens, where the movement of the cross begins at the bottom left and ends at the top right corner.[53] This notion of ascension is lost when the image is flipped (fig. 34).

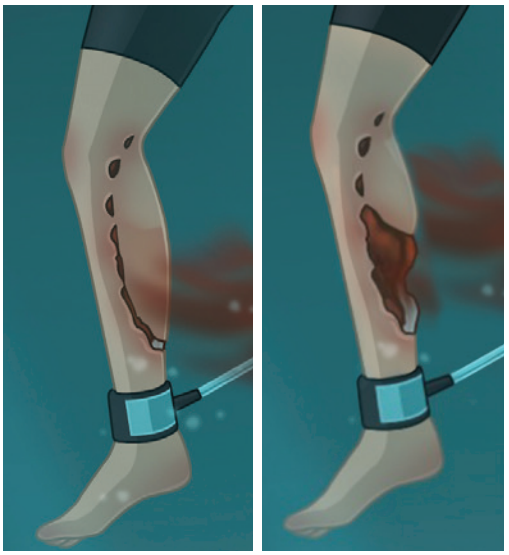


Figure 33. Previous versions with varying degrees of wound severity.

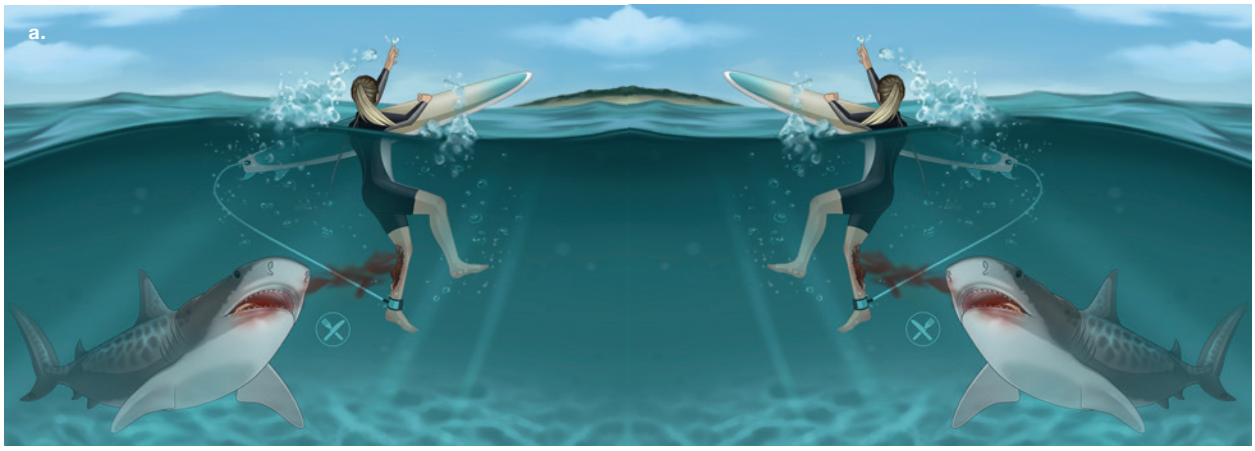


Figure 34. a) The flipped illustration (left) allows for the eye to move from the shark at the bottom left to the surfer at the right sequentially, causing the shark to appear as if it is rising. b) The original elevation of the cross by Rubens (left) versus the flipped version (right). The white arrow indicates the perceived movement of the cross.

7. MIXED MOTIVATIONS

Prof. Clua approached me to illustrate two specific case studies in this chapter. These studies explain how the distinction between motivations is not always clear, as variables present may not be mutually exclusive for one. Together we decided these could benefit from a series of didactic, simple, graphic and monochromatic illustrations. For the first series, I needed to convey how the distance between a rapidly approaching diver (with a scooter and biopsy speargun) and shark, the presence of a rocky cove, or an act of aggression from the diver would define the probability of a territorial (T), anti-predation (A) or defensive (D) motivation. For the second, the location of the bite on a spearfisher or the presence of prey would define the probability of a clumsy (M), competitive (C) or territoriality (T) motivation.

I chose to repurpose the linework for the anti-predation and competition illustrations. Using adobe illustrator, I simplified the existing work by thickening lines and removing details such as gills or belt buckles (fig. 35). I also chose to use graphical elements to denote distances, movement, and regions of focus.

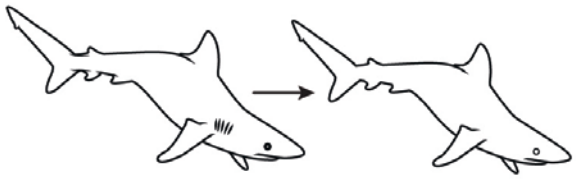


Figure 35. Details were removed from the pre-existing linework to simplify the elements.

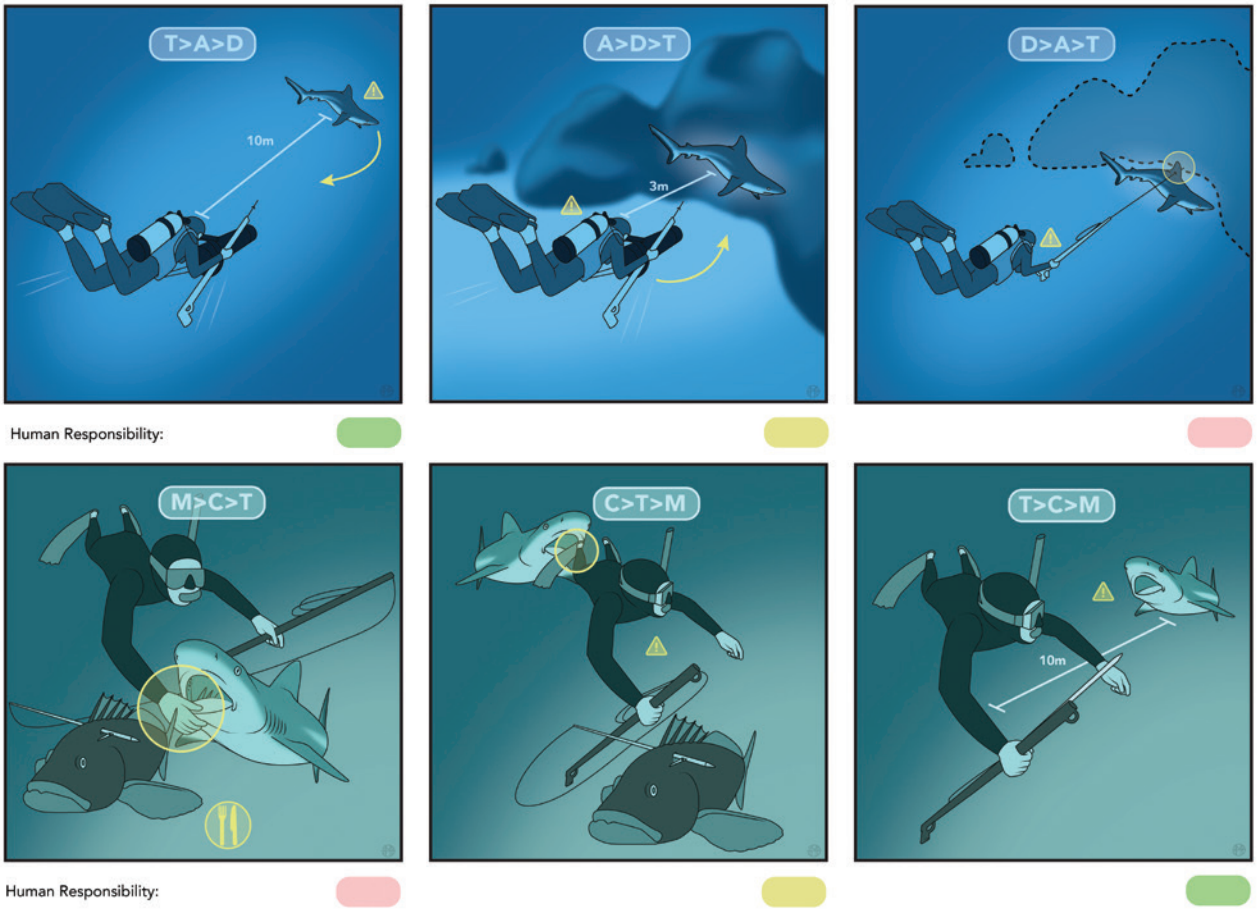


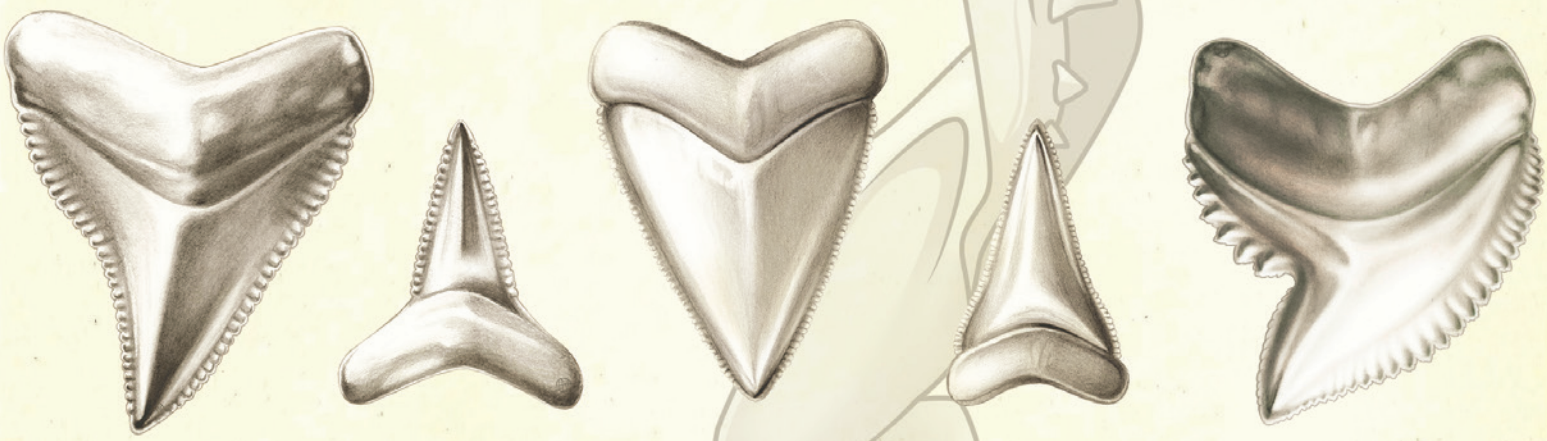
Figure 36. Mixed motivation schematic illustrations. The key relates the colours to human responsibility.

= Low
= Medium
= High

A= Anti-predation
C= Competition
D= Defense
M= Clumsy
T= Territoriality

PART 2

SPECIES-SPECIFIC BITE CHARACTERISTICS



THE INFOGRAPHIC

The main three species implicated in bite incidents are the great white (*Carcharodon carcharias*), tiger (*Galeocerdo cuvier*), and bull shark (*Carcharhinus leucas*).[43] These species share different characteristics in their jaw and teeth structure, which translate to specific bite patterns used in forensic analysis of bite victims. Measurements of bite width (BW), bite circumference (BC) and interdental distance (IDD) allow correlation to the total length (TL) of a shark. This allows specific problem individuals to be found from a database, for proper management.[39]

Prof. Clua requested a graphical representation of the pathognomonic features of species-specific bite injuries. As multiple elements were to be presented together as an overview, it seemed logical to show these as an infographic. Using the material provided and external sources, I compiled my research into a preliminary sketch (fig. 37). The storyline I wanted to display was the bite pattern and how it relates to the anatomy of the jaw and teeth. I also wanted to depict how bites are measured to relate to the total length of the individual shark.

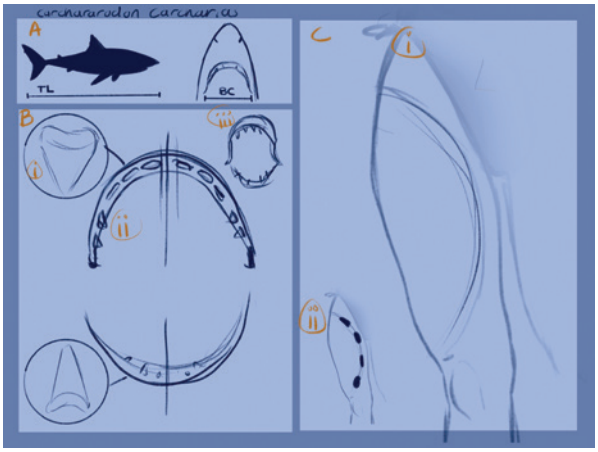


Figure 37. The preliminary sketch for the infographic.

THE ELEMENTS

The first element to illustrate was the bite. The victim's thigh provided a suitable location for elaborations due to its large surface area. Additionally, this region has variation in fat-to-muscle distribution, which would allow me to show how a bite interacts with different tissues.

I chose to illustrate a female thigh due to the higher fat distribution (fig. 38). Furthermore, a women's swimsuit allowed for a larger surface area of the wound to be exposed.

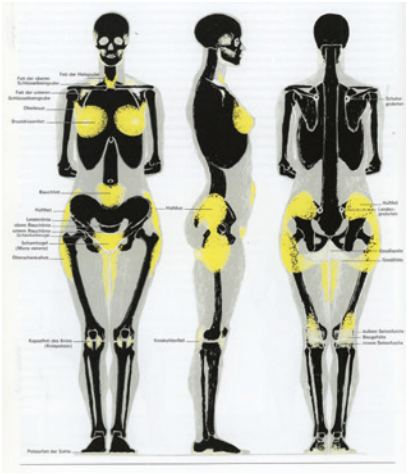


Figure 38. Fat pad distribution on a female.[54]

The second element to include was a clear representation of the species jaw and teeth. Initially, I wanted to illustrate the jaw from the angle at which the teeth would enter the tissue (fig. 39a). After building a clay model, I understood the jaw's curvature would not allow this angle to provide a clear visualisation of key characteristics. A frontal view was more optimal (fig. 39b).

Additionally, I wanted to include a graphical simplification of the bite, where the regions corresponding to each tooth imprint would be related to the jaw illustration through colour coding. The last element I chose to include was a simple silhouette of the shark, to depict how measurements relate to individuals *in-vivo*.[55]

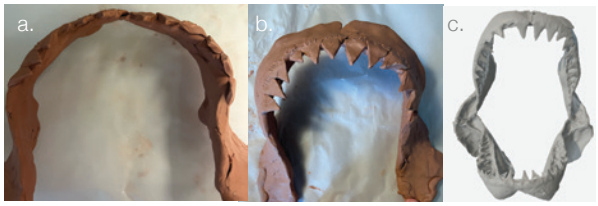


Figure 39. a) A clay model of the jaw of the great white shark seen from below. b) The frontal view of the clay model. c) A 3D model of a great white's jaw.[56]

ILLUSTRATING THE ELEMENTS

Mixing realism with graphical elements proved useful in the first part of this project. I wanted to explore this further and decided to present a range from realistic, graphical to vector illustrations. To execute this infographic, I began with the layout on Adobe Illustrator. Using a colour palette generator, I chose a colour scheme which was cohesive, eye-catching and allowed accents and highlights.[57]

I began by using graphite to illustrate the thigh and teeth (fig. 40). Starting with hard pencils (4H) to carve out the lighter areas, I progressed in layers to softer pencils (3B) for darker areas. This additive technique allowed me to show important details such as tooth serrations. Although most of my references were from the internet, I was fortunate to observe a real specimen of a tiger shark tooth in a micronesian knife at The European Fine Art Fair (TEFAF) (fig. 41). This helped me greatly understand the complexity of the serrations and overall shape. The graphite illustrations then digitally "cleaned" by altering the saturation and curves in Adobe Photoshop. The thigh illustration was then digitally coloured, providing a base for the other species' infographics.

My process of illustrating the bite heavily relied on the chapter written by Prof. Clua, in the book titled *Post Mortem Examination and Autopsy*.[55] Here, a case study on a bite with a circumference of 59.6 cm is discussed. The study concludes this relates to a great white of 3.5m, close to the average size for a male.[36]

Figure 40. Graphite illustration of a tiger shark tooth.

Figure 41. A knife containing tiger shark teeth, from 19th century Micronesia.

I chose to illustrate this size of wound by calculating the width this represented and scaling this to my illustration (fig. 42c,e). This was relatively simple as this illustration was based on my thigh which I could easily measure. Although the circumference was large enough to cover the entire thigh, I chose the area which would represent the imprint of the first ten teeth, similar to what was used in the research I referenced (fig. 42d).[55]

Since the illustration would have to show different tissue layers, I needed to pick the correct colour and texture for these (fig. 42b). Prof. Clua's reference images were ideal for percieving the deeper tissues in wounds and a video of an avulsion thigh lift surgery allowed me to understand the full extent of the tissue layers.[58] With the help of the *Atlas of Anatomy*, I mapped out the muscles and fat pads into this wound region (fig. 42f).[59] On Procreate, I refined the wound edge to match the species-specific pattern described in research (fig. 42g). I then built the topography of the wound using the colours I picked out beforehand, from punctures to deep muscle tears (fig. 42h).

To buffer the shock factor, stylistic decisions were made: I noticed rounding edges of tears in the tissue was less dramatic. Removing highlights on wet or oily tissue such as fat also created this buffer, by removing a degree of three-dimensionality without compromising the entire shape. Elements such as bruising, blood and scratches were excluded as thes not only reduced the illustration's clarity but also added an unnecessary element of "gore". Adding graphical outlines to soft shading allowed me to clarify features and detach the wound from too much realism. Prof. Clua's main feedback was to reduce the size of the skin flaps as these were too wide.

With both my clay model and an online 3D model of the jaw (fig. 39c), I was able to efficiently create a graphical view of the jaw with correct lighting in Adobe Illustrator. Lastly, to fit the look of an infographic, simple vectors of the respective sharks were also created using Illustrator. I focused on main elements such as pattern, colouring, body shape and snout shape to allow a clear identification. I only used three hue variations to add to this simple style.

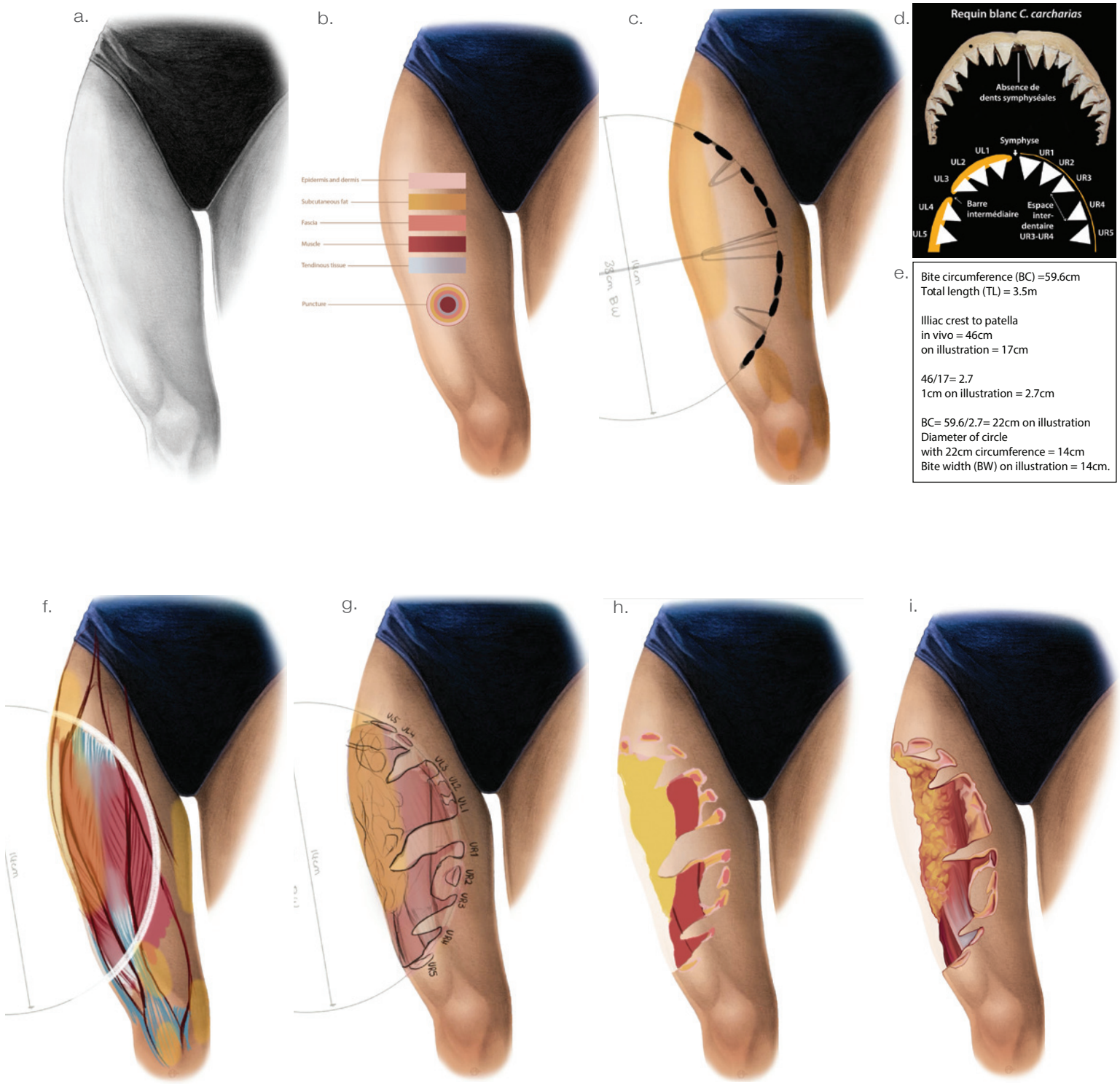


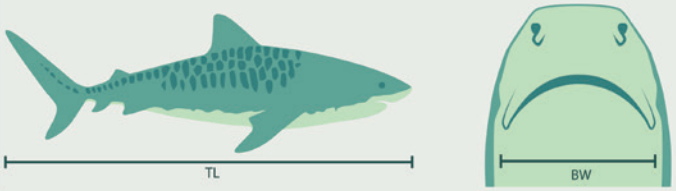
Figure 42. a) The graphite illustration, digitally cleaned. b) The colours chosen to represent the different tissues, and a puncture wound to indicate the heirarchy of tissue layers. c) The area of fat pads and bite mapped out according to the case study by Clua and Reid.[55] d) Schematic representation of the dentition pattern of the upper jaw of the great white along with important spaces.[55] e) The calculation for the bite width based on Clua and Reid's case study.[55] f) The muscles of the thigh mapped out using the *Atlas of Anatomy.*[59] g) Sketch of the wound according to the bite pattern of the great white shark. h) Base colours of the wound. i) Final elaboration of the wound.

Figure 43 (p. 33, ab). Infographic on tiger shark bite characteristics.

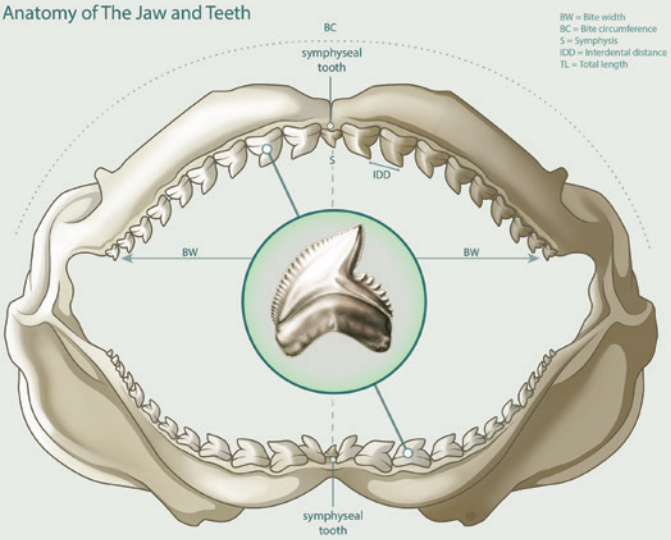
Figure 44 (p. 33, below). Infographic on bull shark bite characteristics.

Tiger Shark Bite Characteristics

Galeocerdo cuvier



Anatomy of The Jaw and Teeth



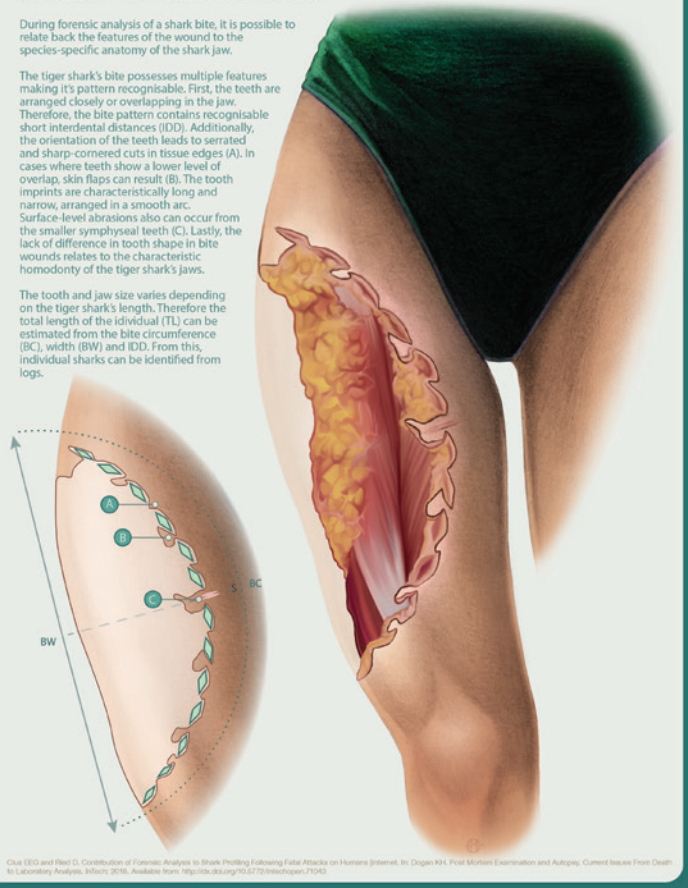
Tiger shark jaws are broad and show dignathic homodonty; all the teeth are similar in shape in both jaws. The teeth share a cockscomb, serrated shape, decreasing in size towards the corners of the jaw. Small symphyseal teeth are present in the upper and lower jaw.

Representation of a Bite on the Thigh

During forensic analysis of a shark bite, it is possible to relate back the features of the wound to the species-specific anatomy of the shark jaw.

The tiger shark's bite possesses multiple features making it's pattern recognisable. First, the teeth are arranged closely or overlapping in the jaw. Therefore, the bite pattern contains recognisable short interdental distances (IDD). Additionally, the orientation of the teeth leads to serrated and sharp-cornered cuts in tissue edges (A). In cases where teeth show a lower level of overlap, skin flaps can result (B). The tooth imprints are characteristically long and narrow, arranged in a smooth arc. Surface-level abrasions also can occur from the smaller symphyseal teeth (C). Lastly, the lack of difference in tooth shape in bite wounds relates to the characteristic homodonty of the tiger shark's jaws.

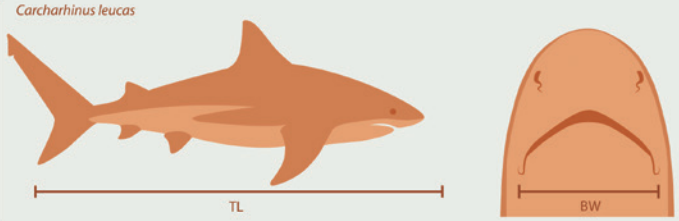
The tooth and jaw size varies depending on the tiger shark's length. Therefore the total length of the idividual (TL) can be estimated from the bite circumference (BC), width (BW) and IDD. From this, individual sharks can be identified from logs.



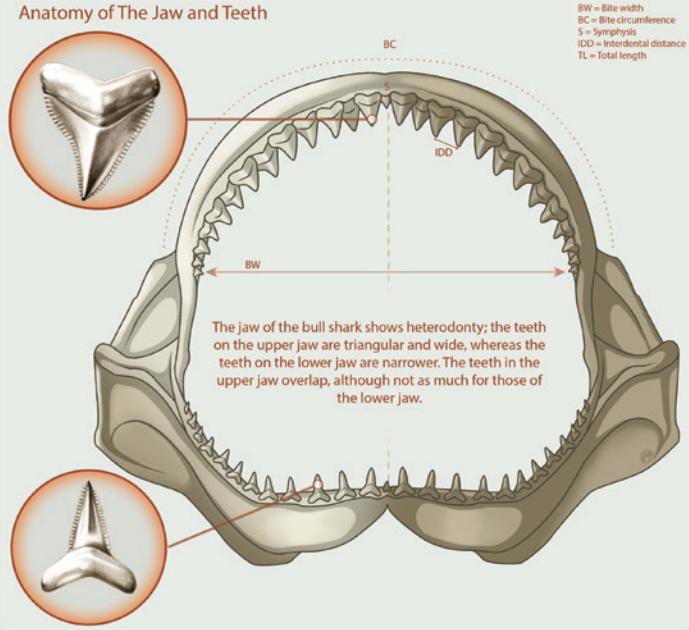
Clua EEG and Fleid D. Contribution of Forensic Analysis to Shark Profiling Following Fatal Attacks on Humans [internet. In: Dogan KH. Post Mortem Examination and Autopsy. Current Issues From Death to Laboratory Analysis. InTech; 2016. Available from: https://dx.doi.org/10.5772/intechopen.71043

Bull Shark Bite Characteristics

Carcharhinus leucas



Anatomy of The Jaw and Teeth

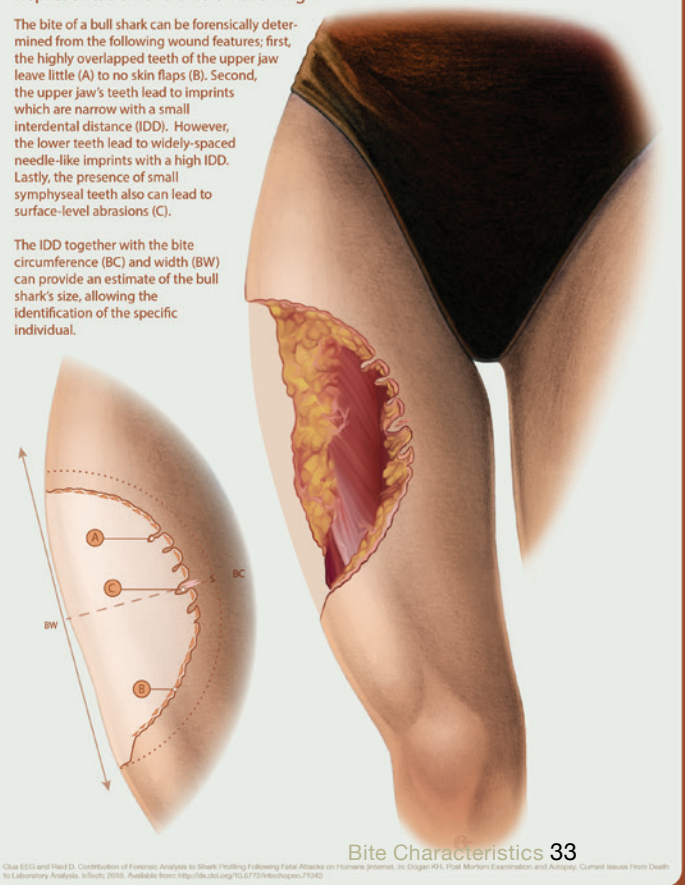


The jaw of the bull shark shows heterodonty; the teeth on the upper jaw are triangular and wide, whereas the teeth on the lower jaw are narrower. The teeth in the upper jaw overlap, although not as much for those of the lower jaw.

Representation of a Bite on the Thigh

The bite of a bull shark can be forensically determined from the following wound features; first, the highly overlapped teeth of the upper jaw leave little (A) to no skin flaps (B). Second, the upper jaw's teeth lead to imprints which are narrow with a small interdental distance (IDD). However, the lower teeth lead to widely-spaced needle-like imprints with a high IDD. Lastly, the presence of small symphyseal teeth also can lead to surface-level abrasions (C).

The IDD together with the bite circumference (BC) and width (BW) can provide an estimate of the bull shark's size, allowing the identification of the specific individual.



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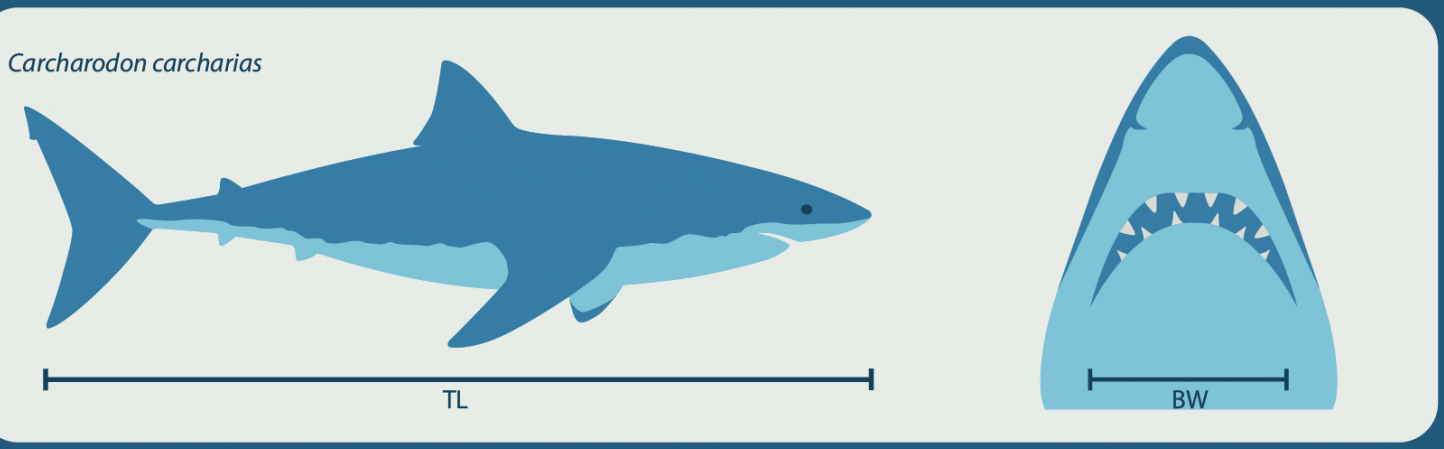
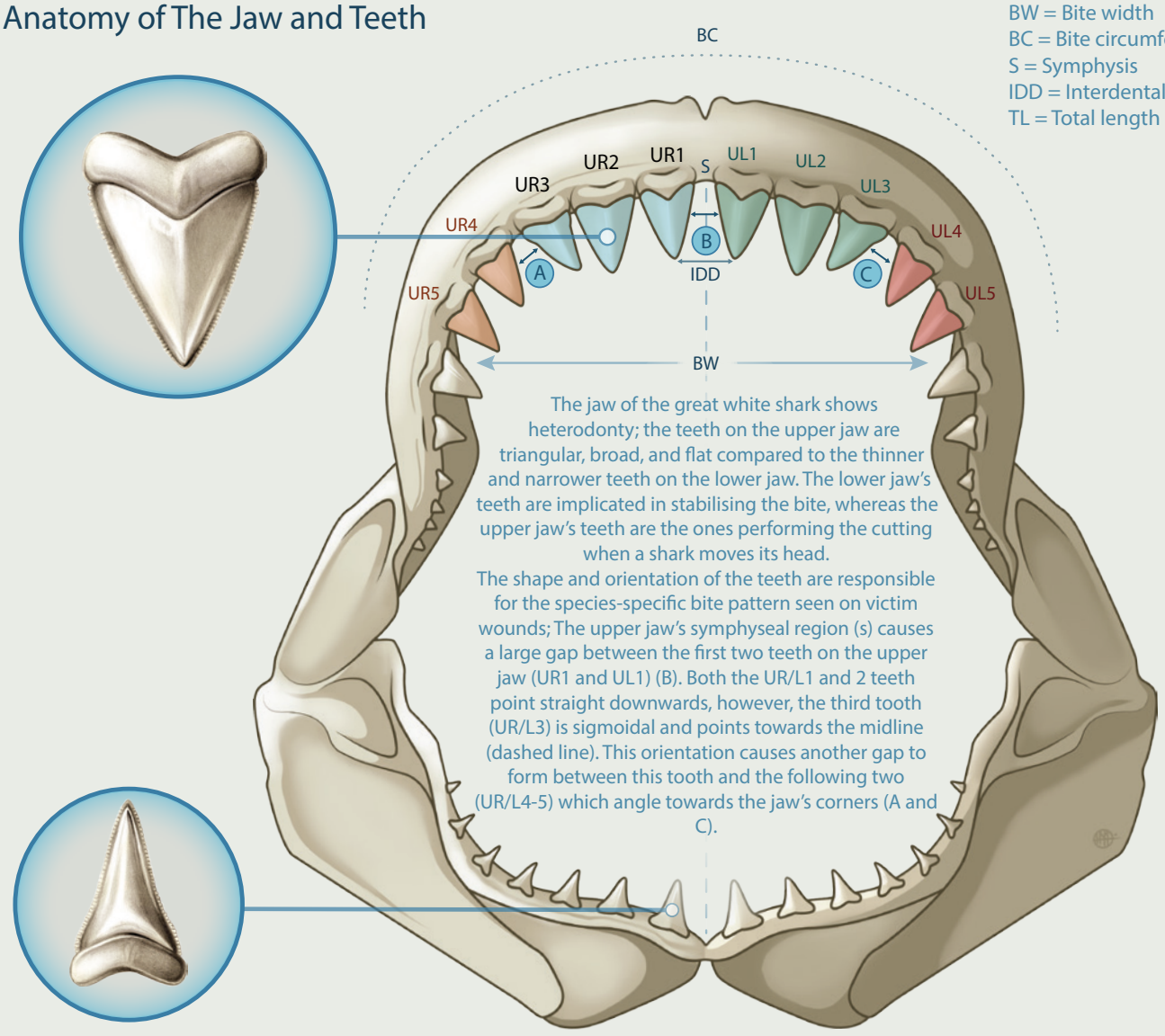
Great White Shark Bite Characteristics



Anatomy of The Jaw and Teeth

BW = Bite width
BC = Bite circumference
S = Symphysis
IDD = Interdental distance
TL = Total length



The jaw of the great white shark shows heterodonty; the teeth on the upper jaw are triangular, broad, and flat compared to the thinner and narrower teeth on the lower jaw. The lower jaw's teeth are implicated in stabilising the bite, whereas the upper jaw's teeth are the ones performing the cutting when a shark moves its head.

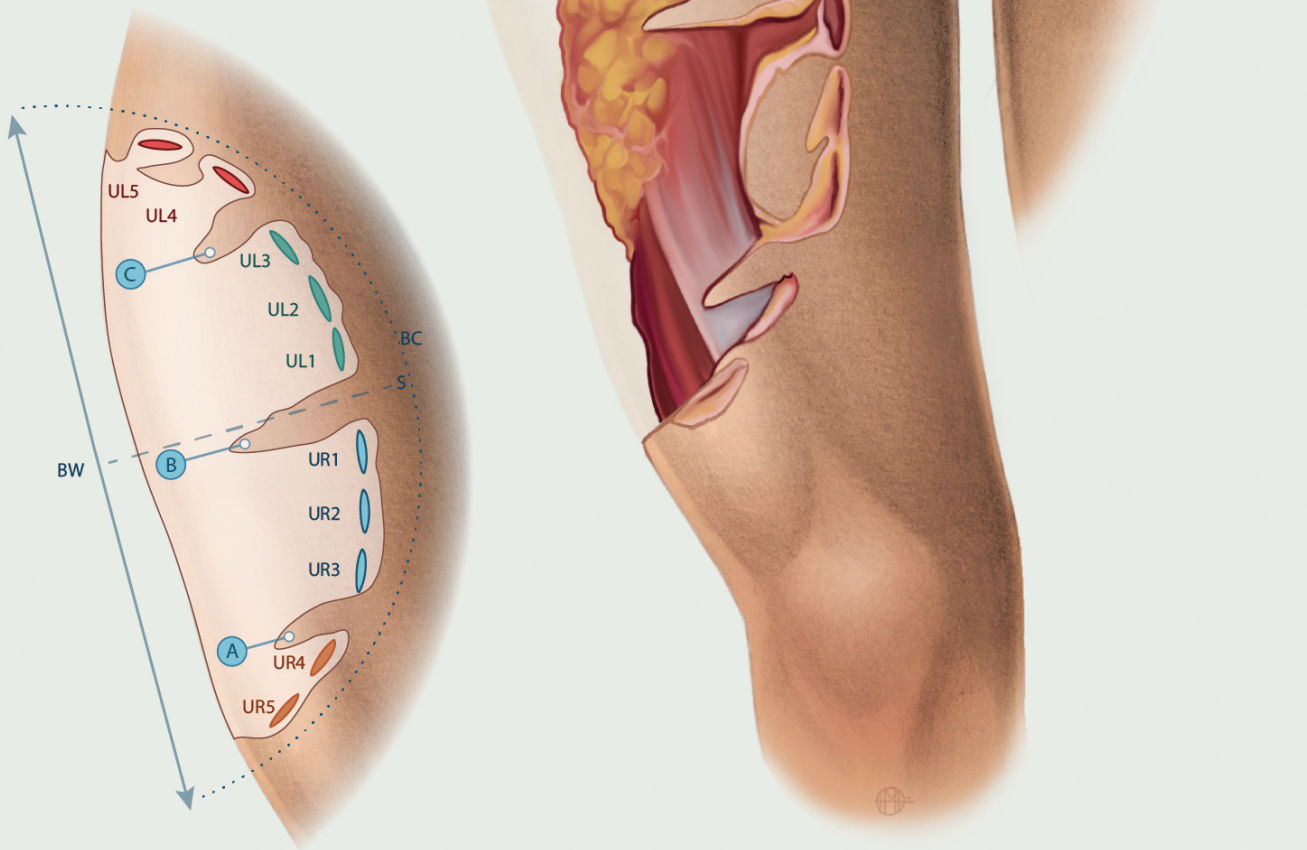
The shape and orientation of the teeth are responsible for the species-specific bite pattern seen on victim wounds; The upper jaw's symphyseal region (s) causes a large gap between the first two teeth on the upper jaw (UR1 and UL1) (B). Both the UR/L1 and 2 teeth point straight downwards, however, the third tooth (UR/L3) is sigmoidal and points towards the midline (dashed line). This orientation causes another gap to form between this tooth and the following two (UR/L4-5) which angle towards the jaw's corners (A and C).

Figure 45. Infographic on great white shark bite characteristics.

Representation of a Bite on the Thigh

In the case of a bite incident, multiple forensic tools can be used to distinguish both the shark species and size. The main characteristics of the great white shark's bite pattern relate back to the gaps in the jaw's structure. These cause the tissue to tear in a specific way, leaving distinctive skin flaps (A,B,C).

Additionally, measuring the bite circumference (BC) and bite width (BW) of the wound can be used to calculate and estimate the total length (TL) of the individual shark behind the bite. In species such as the great white shark, the distance between the tips of the teeth changes depending on the shark's length. Therefore, interdental distance (IDD) also provides an estimate of TL. Using these tools, the responsible problem sharks can be identified from logged individuals and managed appropriately.



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Martin, AR. White Shark Bite Forensics, A Photo Essay [internet]. [place unknown] 2003. ReefQuest Centre for Shark Research [updated 2007; cited 2023 Feb 20th]. Available from: http://www.elasmo-research.org/education/white_shark/forensics.htm

DISCUSSION & CONCLUSION

COVER

The idea that I had for the cover of this thesis was to reverse the narrative of the iconic poster for the movie *Jaws,* painted by Roger Kastel (fig. 46).[61] I wanted to flip the roles of the shark "monster" and the innocent victim. The defensive motivation would represent well the idea that human actions share a role in bite motivations, and that sharks simply interact with their environment. Therefore, I illustrated a human approaching an unsuspecting shark from below with a speargun. To hint at the "retro" look of the original poster, I created the cover using watercolour and mixed media. The style was kept similar to the illustrations in my project to ensure a cohesive feeling.

Through stylistic trial and error and feedback from my external advisor, mentor and peers, the final illustrations in this project were tailored to achieve accurate representation of shark behavior without reflecting negative associations.

I was able to address this by juxtaposing graphical elements to realism; as discussed in this thesis, semi-realism allowed control over the elements which needed to be simplified to avoid the shock factor, and those that would benefit the narrative by showing high detail without over exaggeration. Reducing sharp angles, controlling contrast and removing unnecessary elements proved great tools to achieve this effect. Although these tools are not necessary for all depictions of sharks, I found myself illustrating scenarios which directly addressed the root of this negative connotation seen in popculture. These tools proved helpful at tipping the balance against this, and I hope these provide a good base for any artist approaching this topic.

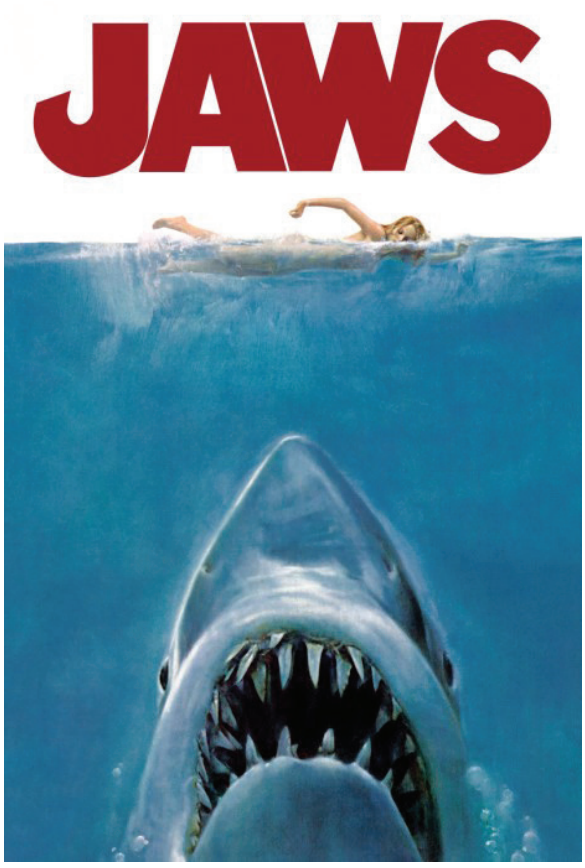


Figure 46. The *Jaws* movie poster painted by Roger Kastel.[12,61]

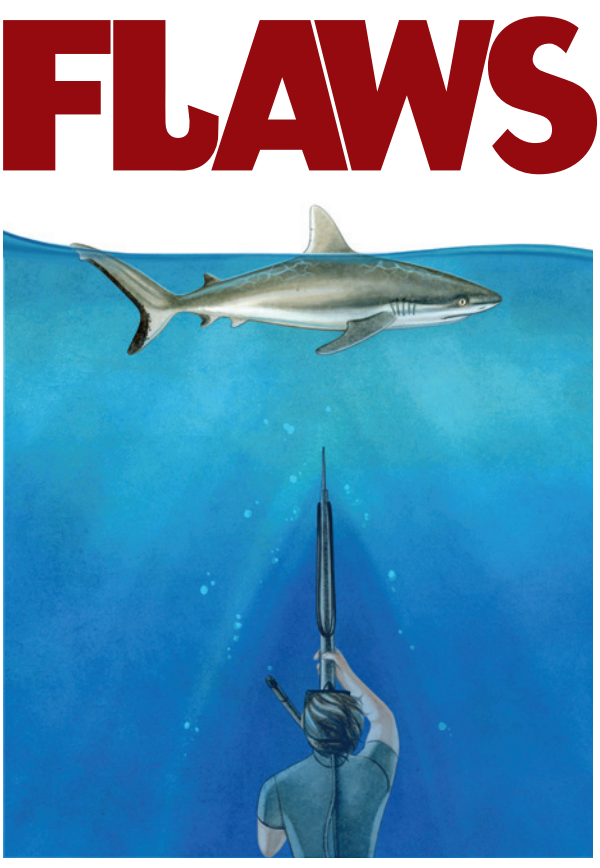


Figure 47. The cover illustration, watercolour and mixed media.

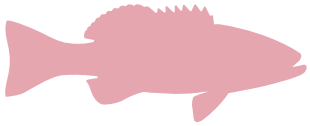
For a reader, subconsciously basing text visualisations on pre-existing associations is easy. Supplementing text with an image based on the factual information presented helps avoid this. As the illustrator, I had a degree of control over the message delivered. Through my own research on the topics and values discussed in the material, I was able to base my illustrations on factual views but also understand the basis of the negative associations and how to avoid these. The addition of visualisations to text also helps attract readers. With the tools mentioned before, I was able to cater these illustrations to reach a larger audience; for readers driven by curiosity expecting or seeking "vulgar" images, these illustrations avoid inaccurate over-dramatisation. Those who shy away from this topic are able to visualise it in a less shocking way. Including illustrations created this way into educational material such as Prof. Clua's, helps a broader audience to obtain a better understanding of sharks.

This project acted as a valuable learning tool for the professional client-artist dynamic. First, I spent much more time than anticipated altering illustrations in feedback loops. Although I managed to create all the high priority illustrations in my initial list for this project, I was unable to create the remaining lower priority ones. In the future I will need to account for more time for the finalisation phase. Second, I learned to focus entirely on my client's wishes; during my reading for this thesis, I found myself in the midst of polarised research. Prof. Clua's work disagrees with some aspects of what is portrayed in popular culture and considered general knowledge of shark behavior. Specifically, it goes against the major classifications used in the ISAF, in which bites are either "provoked" or "unprovoked" in terms of the human's actions and shark's reaction. Prof. Clua's research advocates for the idea that every bite is "provoked" as the shark has an underlying motivation based on its needs. Critical analysis of research was part of my prior biochemistry background. Although I believe it is important to obtain as much knowledge as possible on the topic to be illustrated, I found myself getting off-track reading about such debated theories.

Creating illustrations for one client in a field of emerging research meant that I needed to place all critical thinking behind me and focus solely on the messages conveyed through Prof. Clua's work, as a normal client-artist relation. Luckily for me and my appreciation for these animals, Prof. Clua's values also aligned with my own on the subject of sharks and bites.

While writing this thesis, the previously mentioned fatal New Caledonian incident was interesting to process. Forensic analysis concluded that a tiger shark was responsible, and although this was not disproved, remains were found in a bull shark.[62] This made me understand that this field of research can still meet uncertainties, and more concrete approaches such as DNA fingerprinting would be ideal. A workflow of the DNA fingerprinting process was part of my initial illustration list, however due to time constraints, I was unable to complete this. As I was following the course of the New Caledonian events, I found myself increasingly motivated to create this illustration, and I hope to do so in the near future. Nevertheless, I hope the illustrations already created in this thesis will help the chapter bring a greater push in the application of this alternative approach.

Overall, I believe that my illustrations will aid bring forth the important messages Prof. Clua's chapter has to offer, to a broad audience. Hopefully this is a first step in shedding a better light onto these animals and promoting proper management efforts.



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Contact Information

e-mail: huelvan.margaux@gmail.com

www.margauxhuelvan.com

Maastricht University

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PG | PARENTAL GUIDANCE SUGGESTED

SOME ILLUSTRATIONS MAY NOT BE SUITABLE FOR CHILDREN