

Prevalence and Characteristics of Anthropogenic injuries in oceanic blacktip sharks (*Carcharhinus limbatus*) and bull sharks (*Carcharhinus leucas*) at Aliwal Shoal Marine Protected Area, South Africa.

Marlies Hemelinckx

Bachelor's thesis submitted in order to obtain the
Bachelor's degree in agricultural and biotechnology

BSc degree: Animal care

Supervisor : Nikolaas Colpaert

Academic year 2025-2026
1st exam opportunity – 2nd exam term

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Abstract

Shark species are declining and anthropogenic pressures are on the rise.

This study investigates the occurrence and characteristics of anthropogenic injuries in bull sharks and oceanic blacktip sharks at Aliwal Shoal, Umkomaas, South Africa. The aim is to assess injury frequency, origin, type, anatomical distribution and seasonal variation, as well as the influence of photographic coverage on injury detection.

A total of 383 sharks were analysed, consisting of 53 bull sharks and 330 oceanic blacktip sharks. For bull sharks, 3,975 photographs were systematically reviewed, while 25,354 photographs were analysed for oceanic blacktip sharks. Data was collected using photographic records and classified according to injury presence, number, origin, type and body location. Seasonal patterns were derived from the month of observation and grouped into seasonal categories.

Anthropogenic injuries were recorded in both species, with a substantial proportion of individuals affected. Fishing-related injuries were the most frequent in both bull sharks and oceanic blacktip sharks, followed by vessel-related injuries. Most sharks exhibited a single injury, although multiple injuries per individual were also observed, particularly in oceanic blacktip sharks. Retained fishing gear and associated wounds were the most common injury type, while fins were the most frequently affected body region in both species.

Seasonal variation in newly observed injuries indicated differences in distribution across seasons, with relatively higher frequencies during warmer periods. Photographic analysis showed that a considerable proportion of sharks did not have full-body coverage, suggesting that some injuries may not have been detected and that reported values likely underestimate true occurrence.

Overall, the results demonstrate widespread anthropogenic interaction with sharks at Aliwal Shoal and highlight the importance of fisheries as the main source of injury, as well as the need for improved monitoring methods to better assess impacts on shark populations.

Table of contents

Acknowledgements.....	4
Use of artificial intelligence	5
Abstract.....	6
Table of contents	7
List of Figures	9
1 Introduction.....	11
2 Literature review	13
2.1 Introduction.....	13
2.2 Ecological importance of sharks	13
2.3 Species overview.....	15
2.3.1 Bull sharks	15
2.3.2 Oceanic blacktip sharks	16
2.4 Human-shark interactions.....	18
2.5 Anthropogenic injuries in sharks.....	18
2.5.1 Marine traffic injuries	19
2.5.2 Fishing gear injuries	19
2.6 Shark research and monitoring.....	20
2.7 Methods for assessing anthropogenic injuries on sharks	21
2.8 Aliwal Shoal Marine protected area (MPA).....	22
2.9 Research gap and study relevance	22
3 The empirical section.....	24
3.1 Approach	24
3.2 Materials and methods	25
3.2.1 Study area.....	25
3.2.2 Study species.....	26
3.2.3 Data collection methods.....	27
3.2.4 Data recording	28
3.2.5 Assessment protocol for anthropogenic injuries.....	29
3.2.6 Reducing subjectivity in injury classification.....	31
3.2.7 Ethics and limitations	31
3.3 Results and data processing	32
3.3.1 Data analysis bull sharks	32
3.3.2 Data analysis oceanic blacktip sharks.....	36
3.3.3 Comparison between species	40
3.3.4 Results summary	46
3.4 Discussion and interpretation of the results.....	47
3.4.1 Overview of findings.....	47
3.4.2 Occurrence of anthropogenic injuries.....	47
3.4.3 Injury frequency per individual	47
3.4.4 Origin type and anatomical distribution of injuries.....	48
3.4.5 Seasonal variation in injury frequency.....	49

3.4.6	Photographic coverage and detection bias	49
3.4.7	Limitations and methodological considerations	50
3.4.8	Ecological implications	50
4	Conclusion	51
	Concluding remarks	52
	References	53

List of Figures

Figure 1: Model of the current state of knowledge on the ecological roles and importance of sharks in aquatic food webs (Pacoureaux et al., 2021).....	14
Figure 2: Distribution map of bull sharks (Iucn, 2020b).....	15
Figure 3: Distribution map of blacktip sharks (Iucn, 2020a).	17
Figure 4: Map of Aliwal Shoal	25
Figure 5: Blacktip sharks in Aliwal Shoal 2026.	26
Figure 6: Bull shark in Aliwal Shoal 2026.....	26
Figure 7: Data collection through photo-ID with The Sharkwise Project in 2026.....	27
Figure 8: Overview of the injury recording database for Bull sharks.	29
Figure 9: Injury categories with visualisations.....	29
Figure 10: Occurrence of anthropogenic injuries in examined bull sharks (n = 53).	32
Figure 11: Distribution of the number of anthropogenic injuries recorded per injured bull shark (n = 28).....	32
Figure 12: Origins of anthropogenic injuries recorded in bull sharks, distinguishing fishing-related and boat-related injuries (n = 58).	33
Figure 13: Distribution of anthropogenic injury types recorded in bull sharks (n = 58).	33
Figure 14: Anatomical distribution of anthropogenic injuries recorded in bull sharks (n = 58).	34
Figure 15: Seasonal distribution of newly recorded fishing-related and vessel-related injuries in bull sharks.	34
Figure 16: Completeness of photographic records in examined bull sharks and the occurrence of anthropogenic injuries in individuals with incomplete photographic coverage (n = 53).	35
Figure 17: Occurrence of anthropogenic injuries in oceanic blacktip sharks (n = 330).	36
Figure 18: Distribution of the number of anthropogenic injuries per injured oceanic blacktip shark (n = 155).	36
Figure 19: Origin of anthropogenic injuries recorded in oceanic blacktip sharks (n = 251).	37
Figure 20: Distribution of anthropogenic injury types in oceanic blacktip sharks (n = 251).	37
Figure 21: Anatomical distribution of anthropogenic injuries in oceanic blacktip sharks (n = 251).	38
Figure 22: Seasonal distribution of newly recorded fishing-related and vessel-related injuries in oceanic blacktip sharks.....	38
Figure 23: Completeness of photographic records in oceanic blacktip sharks and occurrence of anthropogenic injuries in individuals with incomplete photographic coverage (n = 330).	39
Figure 24: Comparison of anthropogenic injury occurrence between bull sharks and oceanic blacktip sharks.....	40

Figure 25: Occurrence of anthropogenic injuries in 2 sharks species in Aliwal Shoal (bull sharks and blacktip sharks, n = 383).....	40
Figure 26: Comparison of injury frequency distribution per injured individual between bull sharks and oceanic blacktip sharks.....	41
Figure 27: Comparison of the origin of anthropogenic injuries between bull sharks and oceanic blacktip sharks.....	42
Figure 28: Comparison of anthropogenic injury types between bull sharks and oceanic blacktip sharks.....	43
Figure 29: Comparison of anatomical distribution of anthropogenic injuries between bull sharks and oceanic blacktip sharks.....	43
Figure 30: Seasonal variation in newly observed fishing-related and vessel-related injuries in bull sharks and oceanic blacktip sharks.	44
Figure 31: Completeness of photographic records in both shark species combined and occurrence of anthropogenic injuries in individuals with incomplete photographic coverage (n = 383).....	45

1 Introduction

This bachelor thesis focuses on the prevalence and characteristics of anthropogenic wounds in sharks at Aliwal Shoal Marine Protected Area, with specific attention to oceanic blacktip sharks and bull sharks. Sharks play an important ecological role as apex-predators in global marine ecosystems. However, they are among the most threatened groups in the marine environment due to increasing anthropogenic pressures. Many shark species are targeted, caught as bycatch or unintentionally captured and released during recreational and commercial fishing activities. As a result, several populations face overexploitation and reduced recovery potential. Besides direct mortality, interactions with human activities can also lead to non-lethal injuries such as retained hooks, fishing-line scars, fin damage and propeller wounds. These injuries may affect swimming efficiency, feeding behaviour, reproduction and overall survival.

Although anthropogenic impacts on sharks are increasingly recognized worldwide, information on the prevalence and characteristics of non-lethal wounds in South African shark populations remains limited. In particular, little is known about how wound prevalence and wound type may differ between shark species with different ecological preferences and habitat use. Oceanic blacktip sharks and bull sharks are both commonly encountered at Aliwal Shoal, yet they differ in behaviour, movement patterns and habitat utilization, which may influence the type and frequency of injuries they sustain.

The aim of this study is to investigate the prevalence and characteristics of anthropogenic wounds in oceanic blacktip sharks (*Carcharhinus limbatus*) and bull sharks (*Carcharhinus leucas*) identified through photo-identification at Aliwal Shoal Marine Protected Area. Special attention is given to the type of injury including injuries related to fishing activities and vessel interactions. In addition, seasonal patterns will be examined to determine whether certain injuries may be associated with ecological events such as the sardine run or periods of increased human activity and warmer temperatures.

This study was conducted during an internship at The SharkWise Project in South Africa, where photo-identification techniques were used to identify individual sharks based on fin morphology and assign them a unique shark code. While diving with the sharks and reviewing the photographic database, numerous anthropogenic injuries were observed in both oceanic blacktip sharks and bull sharks. These repeated observations highlighted the frequent interactions between sharks and human activities within the study area and formed the basis for this bachelor thesis.

What is the prevalence and nature of anthropogenic wounds in oceanic blacktip sharks (*Carcharhinus limbatus*) and bull sharks (*Carcharhinus leucas*) at Aliwal Shoal Marine Protected Area (MPA), and how do these injuries differ between species?

To answer this research question, photographic data collected by The SharkWise Project was systematically analyzed. Individual sharks were identified through photo-identification techniques, after which visible anthropogenic injuries were categorized according to wound type. The prevalence and characteristics of wounds were

analyzed separately for both species and subsequently compared to investigate possible links with species-specific habitat use, behaviour and seasonal factors. This thesis first provides background information on shark conservation, anthropogenic threats and the ecology of oceanic blacktip sharks and bull sharks. Subsequently, the methodology used for photo-identification and wound classification is described. The results are then presented separately for each species and comparatively between species. Finally, the results are discussed in relation to habitat use, seasonal patterns and human activities within the Aliwal Shoal Marine Protected Area.

2 Literature review

2.1 Introduction

The modern sharks first appeared around 150 million years ago (Pacoureaux et al., 2021), today there are more than 500 different species of sharks living in the world's oceans (Dedman et al., 2024). It is a well established fact that sharks play a critical role in the structure and function of marine ecosystems (Jorgensen et al., 2021). Understanding the ecology and biology of shark species is crucial for the conservation of these animals (Werry, 2010), with the fact that one third of sharks are at risk of extinction (Santos et al., 2025). The Elasmobranchii are characterized by slow growth, late sexual maturity and low fertility, typically associated with low population growth rates, making them more vulnerable to local extinctions (Cortés, 2000; Dulvy et al., 2021; Jorgensen et al., 2021; Postaire et al., 2023).

There has been a noticeable shift in scientific discourse over time from “sharks viewed as a threat” to “sharks as a threatened species” (Santos et al., 2025). While researchers become increasingly aware of the ecological and socio-economic value of this group, there is a growing effort to assess the extent of human-induced threats and to determine how their impacts can be minimized (Santos et al., 2025). Anthropogenic threats include fishing, pollution, habitat destruction, human activities, marine traffic, and climate change (Santos et al., 2025; Eriksson & Medeiros-Leal, 2026). Raising awareness of this issue can, over time, lead to better education on the matter, encourage change and eventually result in the implementation of more effective solutions (Dulvy et al., 2021). There is still a significant lack of data regarding biology, history, abundance and population impacts of elasmobranchs (Jorgensen et al., 2021). However, when it comes to conservation, understanding these mechanisms and functions is crucial (Dulvy et al., 2021; Marosi et al., 2026).

2.2 Ecological importance of sharks

Sharks fulfill the roles of predators, competitors, catalysts, and transporters of nutrients and food within marine ecosystems. Sharks influence ecosystems through various processes (Dedman et al., 2024). The ecological functions of elasmobranchs include regulating prey populations and supporting stability within the food chain, contributing to nutrient cycling, facultative scavenging, biological control of invasive species and habitat alteration (Jorgensen et al., 2021). Large predatory sharks have an impact on prey species by removing the weak and sick individuals from prey populations (Jorgensen et al., 2021). Additionally, on marine ecosystems by enhancing carbon sequestration (Dedman et al., 2024). Recent findings have shown that sharks play a role in maintaining healthy ecosystems by transporting nutrients across various environments and taxonomic groups (Figure 1) (Pacoureaux et al., 2021).

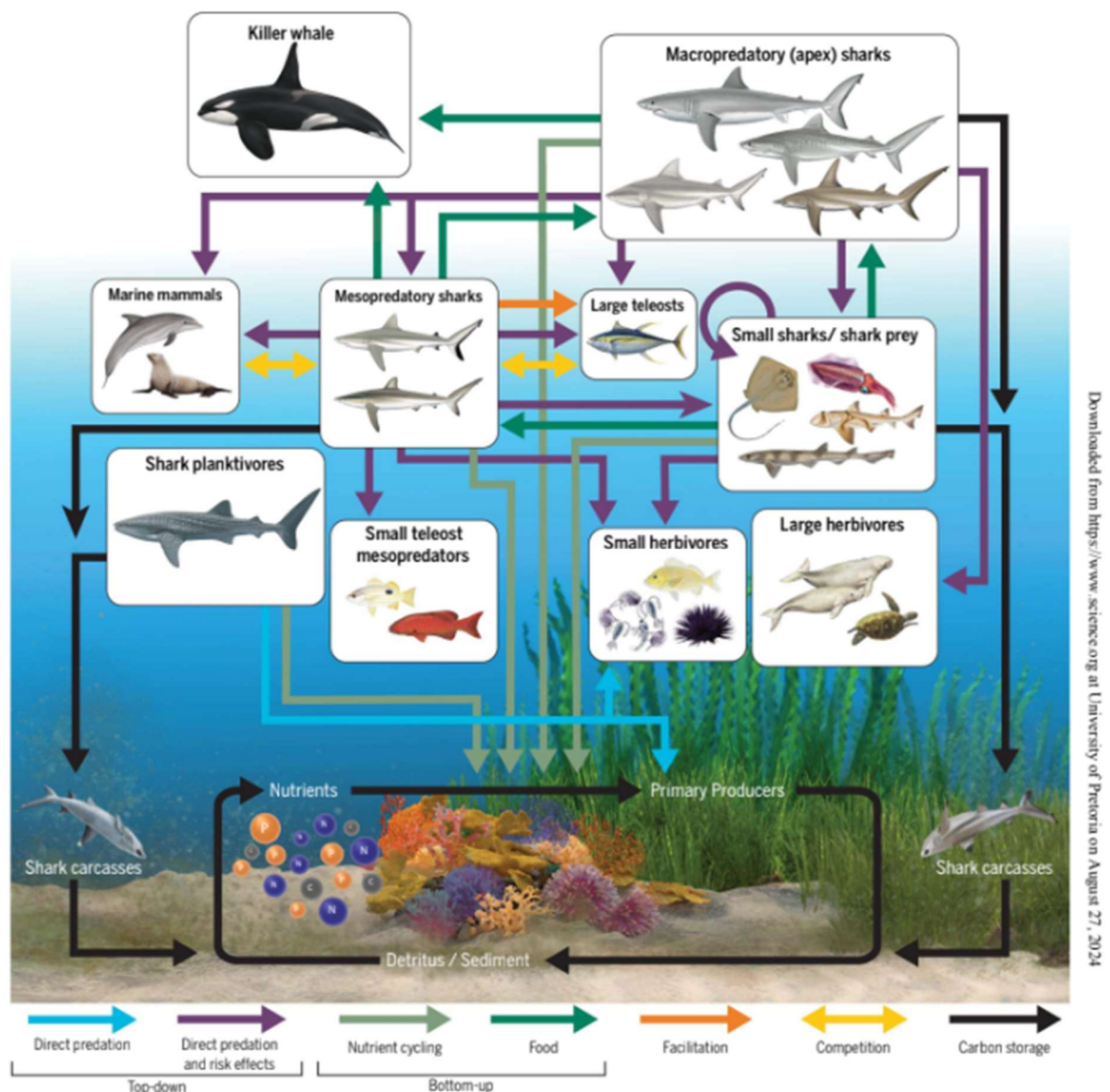


Figure 1: Model of the current state of knowledge on the ecological roles and importance of sharks in aquatic food webs (Pacoureau et al., 2021).

As anthropogenic pressures on sharks increase, there's been a growing concern about the ocean's health declining. This demonstrates that sharks and the health of the ocean are interconnected (Eriksson & Medeiros-Leal, 2026). Research on the importance of sharks has revealed significant ripple effects caused by predatory sharks including the tiger shark (*Galeocerdo cuvier*) and the great white shark (*Carcharodon carcharias*) in areas with seagrass and kelp ecosystems, which influence habitat quality and sequestration of carbon. These indirect effects caused by sharks can strengthen the resilience of ecosystems that are increasingly facing extreme weather conditions. Considering the possible diverse and hidden roles sharks fulfill, the management of shark biodiversity is of great importance. (Dedman et al., 2024).

2.3 Species overview

2.3.1 Bull sharks

2.3.1.1 Bull shark ecology

Carcharhinus leucas, also known as the bull shark is a large, coastal shark species (Karl et al., 2010) found in tropical, sub-tropical and temperate waters worldwide (Figure 2). *C. leucas* is typically located in the demersal zone both inshore and offshore to a depth of 164 meters, generally found at depths of 30 meters (Iucn, 2020b). Its position in food chains, combined with its movement patterns, makes this species ecologically important (Postaire et al., 2023).

Bull sharks have three phases present in the life cycle. The nursery phase (1), regrouping newborns and small juveniles, takes place in sections of rivers with low salinity; the transition phase (2), combining juveniles and subadults, occurring in the transition zone between the estuarine and marine habitats; and the coastal phase (3), consisting of adults found in various coastal and marine habitats (Werry, 2010). Bull sharks are euryhaline and capable of migrating between freshwater and saltwater (Werry, 2010) using estuaries and rivers as feeding and nursery grounds (Pirog et al., 2019). On average, males tend to have more social contacts than females. Variations in social cohesion are also dependent on age classes (Marosi et al., 2026). *C. leucas* is directly affected by various anthropogenic factors: the limited availability of habitat for each life stage makes this species particularly vulnerable to overfishing and habitat change; urban habitats are not ideal habitats for *C. leucas*; the loss of key habitat components and changes in the hydrological regime due to urbanisation have significant negative consequences for populations of *C. leucas* (Werry, 2010). According to IUCN (2020b), the population is declining and their status is classified as vulnerable.



Figure 2: Distribution map of bull sharks (Iucn, 2020b).

2.3.1.2 Bull shark biology

C. leucas belongs to the family Carcharhinidae and is characterized by a short snout, a heavily built body and serrated teeth (Werry, 2010). The total length (TL) of bull sharks ranges from 0.6 to 4 meters (Werry, 2010; Iucn, 2020b). *C. leucas* is a generalist feeder with a significant part of the diet consisting of bony fish, mullet, crabs, seabirds, turtles and other elasmobranchs (Werry, 2010). Bull sharks have the greatest bite force of all cartilaginous fish studied, exceeding that of the great hammerhead and great white sharks (Habegger et al., 2012).

Their euryhaline capacity is attributed to their ability to regulate the main osmolytes in its body fluids including Na⁺, Cl⁻ and urea. This is in order to control the challenges of hyperosmoregulation (Pillans et al., 2005).

Sexual maturity is estimated to occur between the ages of 6 and 8 (Werry, 2010). Bull sharks are a viviparous species with a biennial reproductive cycle (Iucn, 2020b) and litter sizes ranging from 1 to 15 pups (Werry, 2010; Iucn, 2020b).

2.3.2 Oceanic blacktip sharks

2.3.2.1 Oceanic blacktip shark ecology

Carcharhinus limbatus, also known as the oceanic blacktip shark is found in warm-temperate, subtropical and tropical waters worldwide (

) (Merwe et al., 2019; Iucn, 2020a) and is fished in the majority of its range (Smart et al., 2017). This species is typically located along continental and insular plates, above coral reefs and muddy bottoms (Almojil et al., 2018) and are present in large schools near the water's surface. From inshore to a depth of 140 meters, although they are usually found close to the shore (Iucn, 2020a), preferably in temperatures above 21 degrees Celsius (Postaire et al., 2020).

The oceanic blacktip shark can travel distances of more than 2,000 km, with its movements affected by seasonal changes in surface water temperature (Kohler & Turner, 2001). As strong, migratory predators they connect food webs and disperse nutrients across ecosystems (Binstock et al., 2023).

Oceanic blacktip sharks often get entangled in the protective gill nets (shark nets) in South Africa maintained by the Natal Sharks Board (NSB) to protect swimmers on Natal's beaches from shark attacks, resulting in death (Dudley & Cliff, 1993). In the Arabian region, the Gulf of Mexico and the southeast U.S the *C. limbatus* is among the most exploited species (Almojil et al., 2018; Postaire et al., 2020). Its meat is in high demand and is sold in both local and international markets. According to Iucn (2020a), the population is declining and their status is classified as vulnerable.

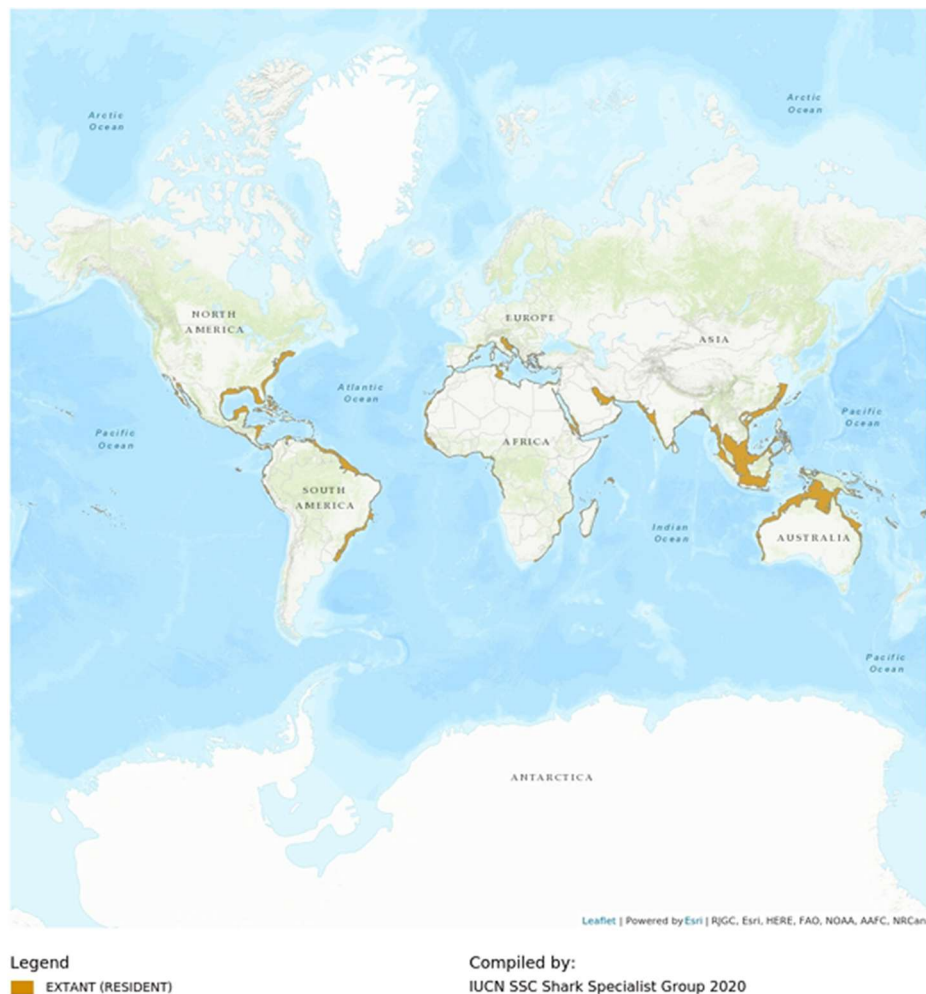


Figure 3: Distribution map of blacktip sharks (Iucn, 2020a).

2.3.2.2 Oceanic blacktip shark biology

The blacktip shark is a fast swimming species (Castro, 1996) reaching a maximum total length of 250 cm (Almojil et al., 2018; Capapé et al., 2021). Research on vertebral aging showed that females and males of the species *C. limbatus* live to be 22 and 24 years old, respectively (Harry et al., 2019). They feed on small bony- and small cartilaginous fish (Castro, 1996).

C. limbatus is a viviparous species with a reproductive cycle of two years and including a biennial ovulation cycle with a gestation period of 10-12 months (Castro, 1996; Postaire et al., 2020). The litter sizes range from 1 to 8 pups (Capapé et al., 2021; Iucn, 2020a). Shallow coastal waters are used as nurseries where juveniles spend their first few months of their lives (Almojil et al., 2018). The natural mortality rate among newborns is highest during the first 15 weeks of life (Postaire et al., 2020). Females show reproductive behavior, such as the tendency to remain in their place of birth which can lead to limited genetic exchange in this species (Almojil et al., 2018). Adult males can be distinguished from immature males by their claspers, which are elongated and calcified, whereas in females, size at sexual maturity (50%) can be used to distinguish between immature and adult individuals (Postaire et al., 2020).

2.4 Human-shark interactions

Both fear and fascination encompass the human perception of sharks. On the one hand, admiration for these creatures has led to extensive fundamental scientific research and their current critical situation has been the source of worldwide funding for conservation research. On the other hand, efforts to seek solutions to the inevitable conflict between humans and sharks can be overshadowed by the public's fear of shark "attacks." As a consequence, extermination programs targeting endangered species are often employed to appease public perception (Sabatier & Huveneers 2018).

Coastal areas, including the shorelines of lakes, rivers and streams have always been popular human habitats because they provide easy access to water, food, building materials, transportation and recreation (Werry, 2010). As human and shark habitats overlap gradually, injuries caused by human activities including marine debris, collisions with ships, scientific research and fishing are becoming increasingly common. These injuries often lead to long-term physiological malfunction, behavioral changes and even death (Black, 2023).

Due to the osmoregulatory capacity of *C. leucas* this species is able to utilize a wider variety of coastal habitats than most other sharks, making it one of the shark species most likely to be regularly found in urban areas and involved in shark-human interactions. *C. leucas* is therefore threatened by a conflict between the impacts of the growing human population, its own inherent biological adaptability to estuarine ecosystems and its apparent ability to exploit urban environments (Werry, 2010).

Although encounters with sharks are rarely fatal, changes in human behavior such as gathering in large groups, handling, and feeding sharks are altering the natural behaviour of sharks, particularly in areas affected by human activities (Zemah-Shamir, 2025).

2.5 Anthropogenic injuries in sharks

For centuries, human activities have been affecting the oceans (Eriksson & Medeiros-Leal, 2026; Dulvy et al., 2021), both directly through fisheries and hunting and indirectly through habitat destruction and climate change (Dulvy et al., 2021). Growing anthropogenic factors such as aquaculture, nature tourism and resource extraction, including fishing, are causing interactions between sharks and humans to become progressively more diverse (Dedman et al., 2024; Eriksson & Medeiros-Leal, 2026). The global trade in shark fins and liver oil continues to be a significant cause in overfishing and death in sharks (Cardenosa et al., 2026).

Human-related injuries inflicting physical and ecological impacts are observed in many shark species. These events pose considerable concerns as these wounds may be threatening to an individual's health and survival (Yee, 2024).

Globally, the amount of anthropogenic waste in the ocean is increasing. Fishing gear is often lost at sea due to wear and tear over time or as a result of poor weather conditions. This gear can be described as lost, neglected or discarded fishing gear.

It is also referred to as “ghost gear,” which can drift passively across the oceans, continuing to entrap and hurt other marine life (Parton et al., 2019).

Many large sharks that hunt near the ocean surface sustain injuries from collisions with boats and contact with stationary fishing gear (Anderson et al., 2025).

All wounds involving skin damage exhibit a visually recognizable healing process expressed in a change in color: from red or pink when the wound is fresh, to white and eventually black as it heals. However, if the wound is not covered by newer scars, it can still remain visible for decades (Anderson et al., 2025). The ability to heal external injuries is a crucial trait for the survival of vertebrates (Heim et al., 2023).

2.5.1 Marine traffic injuries

Global marine traffic is on the rise as the global economy grows, posing a growing threat to a large number of marine megafauna species (Womersley et al., 2022) considering the continuing decline of certain species (Chapple et al., 2024). A collision or impact with a vessel is defined as any contact between a part of a vessel (usually the bow or the propeller) and a marine animal (Schoeman et al., 2020). Boat propellers can cause major injuries to sharks that can be fatal in severe cases. As the propeller spins, it leaves behind a series of clean, straight and equally spaced parallel cuts. Most propeller cuts occur in the middle of the upper back and the dorsal fin and sometimes in the caudal fin (Anderson et al., 2025).

These wounds caused by vessels contribute to poor body condition in affected individuals (Yee, 2024). Various marine species in estuarine and coastal waters are particularly at risk of collisions with small and medium-sized vessels, which are found in large numbers near urbanized coastal areas (Schoeman et al., 2020). Estimates of the risk of collisions correlated with reported mortality rates from collisions with ships, suggesting that mortality is higher in areas where the data overlap most closely. A significant challenge in assessing global mortality among marine animals resulting from collisions with vessels is the lack of direct observations, sharks sink when they die, meaning that the vast majority of deaths remain undetected or are not reported (Womersley et al., 2022).

2.5.2 Fishing gear injuries

The concept of “fishery conflict” is often vaguely defined and is sometimes applied to a wide range of situations, without taking into account the varying degrees of conflict (Eriksson & Medeiros-Leal, 2026). Direct and indirect fishing pressures are global threats for sharks. These anthropogenic activities can result in the embedding of fishing gear within shark tissues and related injuries following an interaction. One of the most harmful ramifications associated with targeted and bycatch fisheries is the loss and subsequent embedding of hooks in marine life (Ward et al., 2007; Yee, 2024). The impacts of retained hooks on sharks in commercial fisheries was studied by Mucientes and Queiroz in 2019. The study found that retained hooks can result in a range of critical pathologies; including stomach perforation, ulceration, esophagitis and hepatitis, often causing death (Mucientes & Queiroz, 2019).

If a fishing line becomes entangled with a shark, it can rub against the skin, leaving a white mark (“line burn or rope burn”) that sometimes reveals the spiral twist of the line. The line can get caught on the fins, causing the shark to roll, which in turn causes the line to scrape against the skin. In many cases, the fishing gear is easily recognizable, such as sport fishing gear that is caught on their fins or mouth (Anderson et al., 2025). It has been observed that, even though they are classified as bycatch, fishing activities appear to closely follow the seasonal migration patterns of sharks (Eriksson & Medeiros-Leal, 2026).

The location where the fishing gear is attached can be classified as “internal,” in which case no hook is visible and the nylon or steel line protrudes from the mouth, gill slits, or cloaca, or “external,” in which case the hook is attached and visible in the shark’s mouth or at other external attachment points (Bansemer & Bennett, 2010b). Entanglement with fishing gear can lead to suffocation, starvation, restricted movement, and eventually death (Parton et al., 2019).

Injuries to the mouth and jaws are a separate degree of conflict with the possibility of having an impact on the animals’ ability to hunt and feed. These injuries include tissue necrosis and abscesses extending around the area where a hook was previously attached, dislocation and fractures of the jaw and healed injuries that have left permanent deformities. Mandibular injuries caused by fishing gear are diverse and get progressively worse over time (Bansemer & Bennett, 2010b).

Negative interactions between sharks and fisheries is undeniably a prolific animal welfare and conservation issue (Parton et al., 2019).

2.6 Shark research and monitoring

Unlike animal research on land, marine research is restricted by factors such as limited bottom time, limited air, underwater conditions, safety rules and film capacity (Köhler & Köhler, 1999). Furthermore, the study of sharks in their natural habitat poses challenges due to their migration patterns and elusive behaviour, resulting in limited knowledge about shark species (Maroen et al., 2024). These challenges can be partially overcome through the use of photo identification (Maroen et al., 2024; Lionnet et al., 2025).

Photo-identification is an increasingly popular and non-invasive technique used for animal research. It can be used to identify individuals, track migration patterns of the animals, monitor populations and assess health (Lionnet et al., 2025). Sharks are dependent on conservation measures and the competency to identify individuals is crucial (Maroen et al., 2024). Photo-identification has often been used to identify cetaceans in the past (Katona et al., 1979), it is also currently used to identify a variety of shark species (Maroen et al., 2024).

The most important feature for identifying sharks, is the notches on the trailing edge of the first dorsal fin (Andreotti et al., 2016). To improve objectivity, physical

characteristics, such as pigmentation, scars, wounds and height can be included to assist in the identification of individuals (Maroen et al., 2024; Schilds et al., 2019). Although it is an extremely useful tool, the photo-ID method can also be subject to researcher bias, and with large databases, matching individuals observed on multiple occasions becomes a time-consuming process (Maroen et al., 2024).

Once a digital photo database has been compiled, various forms of image processing can be used to distinguish individuals from one another. This includes manually comparing photos, using semi-automatic or fully automatic computer-assisted methods (Pierce et al., 2018). The traditional manual approach involves side-by-side comparison of dorsal fin images in a database consisting of previously identified shark images (Anderson et al., 2011). In traditional databases, stored images are labeled based on the date they were taken. Processing such a database is a labor-intensive task, and the likelihood of incorrect matching due to human error (or poor-quality photos) increases as the photo database grows (Andreotti et al., 2014).

In an effort to reduce the labour intensity of the linking process, Andreotti et al. (2014) came with the idea of using a “notching-code- method” by assigning a unique three-part code to each photo of a dorsal fin. Although this method appears to offer a better solution than the traditional manual method, the notch code can also be influenced by the user’s subjectivity when assigned (Andreotti et al., 2014). The use of computer-assisted software and machine learning algorithms can offer a better alternative by minimizing user subjectivity in the matching process, ensuring high matching accuracy and also reducing processing time (Maroen et al., 2024; Andreotti et al., 2017). It is the case that all semi-automatic methods use built-in algorithms to suggest the most likely matches, but it is the person using the system who makes the final decision when confirming the match (Andreotti et al., 2017). The fully automatic computer-assisted software developed for marine mammals proved unable to accurately match the photo IDs of white sharks (Andreotti et al., 2016).

2.7 Methods for assessing anthropogenic injuries on sharks

To study anthropogenic wounds in sharks using a non-invasive method, videos and photos of individual sharks can be recorded (Anderson et al., 2011; Anderson et al., 2025). Before analyzing injuries, a systematic classification system can be developed for the various types of injuries and scars frequently observed in sharks and associated with anthropogenic impacts. This systematic approach provides a key to a more efficient and consistent classification of injuries, which may also be applicable to numerous other marine organisms for which imagery is available over a long period of time. (Anderson et al., 2025).

2.8 Aliwal Shoal Marine protected area (MPA)

In marine protected areas (MPAs), human activities within their boundaries are regulated to support the conservation of marine ecosystems in the long term and the associated benefits for the human population. It is based on an understanding that the community and stakeholders play a vital role in its success through their participation, support, and cooperation (Francolini et al., 2023). More and more MPAs are being designated to protect endangered species (Vaudo et al., 2026). The importance of managing marine protected areas lies in the fact that they are shared spaces where nature conservation and public safety intersect (Zemah-Shamir, 2025), but it is unclear to what extent these areas are effective in protecting species with a wide range (Vaudo et al., 2026). A serious threat to shark protection in marine protected areas is illegal, unreported, and unregulated fishing (IUU fishing) (Castrejón, 2025). In South Africa illegal bottom fishing is taking place in MPAs (Shabangu et al., 2025).

Aliwal Shoal is a remarkable underwater reef off the coast of Umkomaas, south of Durban on the southern coast of KwaZulu-Natal in South Africa (Schleyer et al., 2005). Aliwal Shoal is known as 'The Greatest Shoal on Earth' and got designated as a Mission Blue Hope Spot in 2014 (Comms, 2026).

An analysis conducted by Francolini et al. (2023) in Aliwal Shoal revealed several challenging issues, including: lack of compliance with existing regulations; inadequate enforcement of maritime laws; corruption at the national level; poor physical infrastructure and regulations governing marine protected areas that are perceived as racially biased (Francolini et al., 2023). It is deeply concerning that regulations in Aliwal Shoal and other MPAs are being violated with no consequences, thereby undermining the research objectives, socioeconomic development and conservation of these areas (Shabangu et al., 2025).

2.9 Research gap and study relevance

Sharks are among the most endangered groups in the marine environment, with 24% of shark populations considered to be at risk of extinction due to various human-induced threats (Parton et al., 2019). Furthermore, more than 75% of chondrichthyans species in tropical and subtropical coastal and open ocean areas are threatened, indicating a large-scale loss of ecological functions (Dulvy et al., 2021). Global shark populations have declined by approximately 71% since 1970 (Pacoureau et al., 2021). Threats to chondrichthyan fish species can be predicted based on body size and average depth of residence with larger species facing a greater risk of threat than smaller species (Dulvy et al., 2021). While conservation research and concern for elasmobranchs is growing, there is still a paucity of data for many marine species, human-shark interactions, risks to population survival and efficacy of conservation interventions. Sharks are subject to overexploitation, risk of extinction and consumption of their meat and fins. They are targeted by fisheries or caught as bycatch (Jorgensen et al., 2021).

Injuries caused by boats, gear entanglement and fishing have been described for whale sharks (Speed et al., 2008) and white sharks (Towner et al., 2012; Anderson et al., 2025), leaving a gap in the knowledge base for bull sharks and blacktip sharks. Borucinska et al. (2002) concluded that the effects of retained hooks on shark health requires further investigation. The survival of several shark populations is a global concern. Many shark species that are commercially fished, caught as bycatch and processed, or accidentally caught and released by recreational or commercial fishermen, are at risk of overexploitation and potential extinction (Bansemer & Bennett, 2010).

Fishing continues to pose a significant threat to species and is likely to reduce the potential for population recovery (Bansemer & Bennett, 2010b). Sharks exhibit negative buoyancy; subsequently, the bodies of animals paralyzed or killed by anthropogenic injuries will sink. Given that carcasses are rarely recovered, the deaths often go unrecorded or undocumented (Lester et al., 2019). There is an urgent need for the fundamental scientific research required to conserve sharks (Almojil et al., 2018). Methodological profiles point to persistent gaps in the research and potential geographical and taxonomic biases that need to be addressed to improve global understanding of the future of sharks in the oceans and improve evidence-based conservation and management policies (Santos et al., 2025).

As the human footprint continues to grow and shark populations continue to decline, it is crucial that we understand how human activities affect sharks and related species (Santos et al., 2025). The considerable and increasing risk of extinction among chondrichthyes indicates that the conservation measures taken to date are seriously inadequate, that they are poorly enforced and/or not being implemented, thereby failing to halt the decline of nearly all species (Dulvy et al., 2021). Although a change in the fishing industry, conservation and recovery goals will be challenging due to economic factors and the damage caused by fishing, they are necessary to ensure healthy ecosystems in a changing ocean (Dedman et al., 2024). It is a pressing challenge to stop the decline in populations and limit the risk of extinction to a minimum, in order to reverse the trend of marine biodiversity loss. To counteract the threat of shark species becoming endangered, fisheries must be managed sustainably through catch limits based on scientific advice and this can only be achieved with sufficient supporting evidence. (Dulvy et al., 2021).

Thus, shark populations are rapidly declining, which makes it clear that something must be done to address the knowledge gaps that could hinder conservation efforts (Carabelli et al., 2025). Education is necessary as a human's perception is shaped by his or her experiences, values, knowledge and beliefs. An individual will protect what they understand (Francolini et al., 2023).

3 The empirical section

3.1 Approach

This study used an observational and comparative approach to assess the prevalence and characteristics of anthropogenic injuries in two co-occurring shark species at Aliwal Shoal Marine Protected Area. The injuries and scars observed on the animals were used as indicators of interactions with human activities related to fishing as well as marine traffic.

A distinction was made between blacktip sharks and bull sharks to assess whether species-specific habitat use influences the prevalence and type of injuries inflicted. Blacktip sharks are generally more pelagic and occur in larger groups, while bull sharks are more commonly associated with coastal and estuarine environments and rather exhibit solitary behaviors. These ecological differences may lead to varying exposure to anthropogenic threats, such as fishing gear and vessel activity. Visual footage of bull sharks and blacktip sharks in Aliwal Shoal has been collected and analyzed for human-caused injuries.

These injuries were categorized based on visible characteristics (Figure 9), including linear cuts, hook injuries, propeller scars, perforations, abrasions, amputations and unusual scarring. This classification made it possible to identify potential causes of injuries and make a comparison between species.

The analyses focused on the percentage of individuals with human-caused injuries, the frequency and types of injuries observed per species and patterns in the occurrence of injuries in relation to species-specific behavior and habitat use.

By linking the observed injury patterns to ecological characteristics and human activities, this approach aims to provide insight into the extent and nature of human impact on shark populations in the study area.

3.2 Materials and methods

3.2.1 Study area

The study was carried out at Aliwal Shoal (Figure 4), a rocky reef located off the east coast of South Africa, approximately 4-5 km, 5 kilometres offshore from the town of Umkomaas in the province of KwaZulu-Natal. Aliwal Shoal is a Marine Protected Area (MPA) and was recognized as a Mission Blue Hope Spot in 2014. The Shoal is the focus of a wide range of sustainability, tourism, conservation and research initiatives (Website, z.d.).

Aliwal Shoal is a complex reef structure with ridges, peaks, and sandy areas at depths ranging between 10 and 30 m. The area is exposed to dynamic oceanographic conditions, including strong currents, wave action and variable turbulence influenced by river outflow, particularly from the nearby Umkomaas River. Water temperature typically ranges between 20 and 26 °C, with visibility varying between approximately 8 and 30 m, depending on seasonal and environmental conditions. Aliwal Shoal is accessible by boat after launching from the Umkomaas river mouth (Goldberg & Ayerst, 2006). Data collection took place at two dive sites using baited shark dives (hereafter referred to as the “northern” and “southern” sites), located approximately:

- North site: ~30°14.985' S; 30°49.779' E
- South site: ~30°17.696' S; 30°49.295' E

Aliwal Shoal is globally recognized as a hotspot for sharks, home to a wide variety of large predatory species. The ecological significance, combined with the predictable presence of sharks at dive sites where bait is deployed, makes the area particularly well-suited for behavioral and ecological research on large sharks.

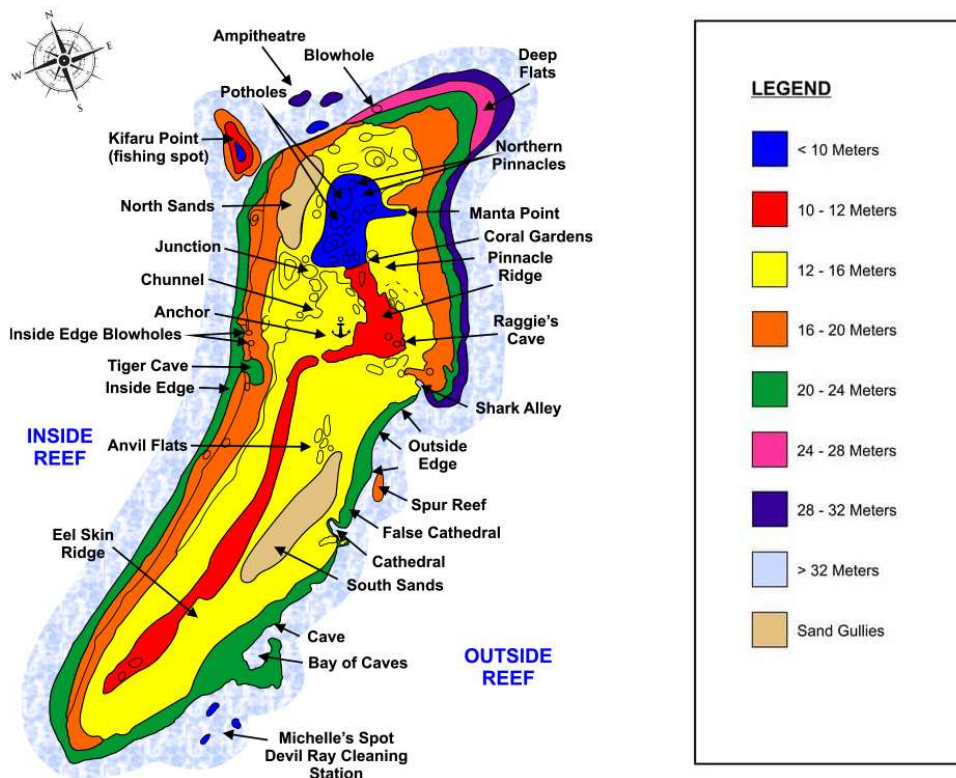


Figure 4: Map of Aliwal Shoal

3.2.2 Study species

Oceanic blacktip sharks and bull sharks (the latter locally known as Zambezi sharks) are of particular interest in this study, as the two species are common in the region while greatly differ in their ecology and behavioral patterns.

The blacktip shark (Figure 5) is a highly mobile, schooling species that is common in coastal and pelagic environments. At Aliwal Shoal, this shark is present in relatively large numbers year-round and shows a strong association with diving activities involving bait. The sharks form dynamic, multi-individual feeding groups that can consist of dozens of sharks.

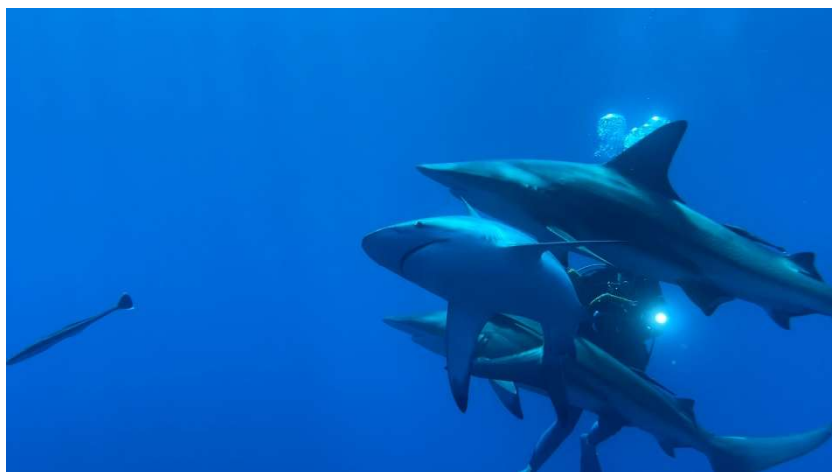


Figure 5: Blacktip sharks in Aliwal Shoal 2026.

The bull shark (Figure 6), on the other hand, is a more robust, solitary, and opportunistic top predator known for its tolerance of a wide range of salinity levels and habitats, including estuaries. At Aliwal Shoal, bull sharks are less predictable and are typically observed as solitary individuals or in small numbers, often within mixed-species groups. Their presence is more seasonal, with generally more sightings during the warmer months. They tend to stay lower in the water compared to oceanic blacktip sharks.



Figure 6: Bull shark in Aliwal Shoal 2026.

3.2.3 Data collection methods

3.2.3.1 Dive protocol

The data was collected through repeated baited shark dives conducted at Aliwal Shoal with the SharkWise Project over the sampling period, which began on December 6, 2020 (sampling ID: 2020120601). During the internship period, from January 31st, 2026, to May 1st, 2026, additional data was collected during dives and processed in the database. All dives took place at depths between 6 and 10 m, ensuring consistent observation conditions during all sampling sessions. Each dive lasted approximately 60 minutes, providing sufficient time to record the presence of individual sharks.

The dives were conducted in the morning, usually before noon, to minimize variations caused by the day-night cycle in shark activity and environmental factors such as light conditions and water currents. Baited shark dives in this region involve the deployment of a bait drum containing sardines. The use of bait creates a persistent olfactory stimulus in the water column, which enhances local predator density and increases the frequency of encounters.

During each dive, the bait drum was deployed to attract sharks, creating a controlled observation environment in which the animals could be consistently observed (Figure 7). This standardized diving protocol ensured that the various sampling rounds were comparable and maximized the likelihood of observing both target species.

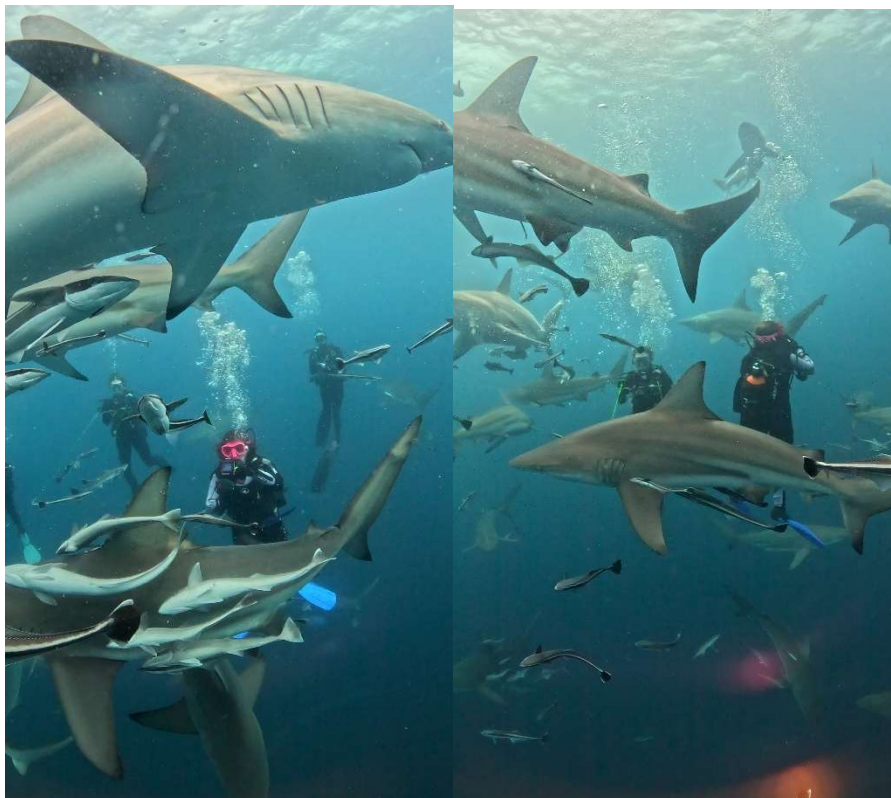


Figure 7: Data collection through photo-ID with The Sharkwise Project in 2026.

3.2.4 Data recording

3.2.4.1 Photo-identification

The visual data collected was obtained using underwater cameras, including Olympus Tough with PT-059 waterproof Tough housing, GoPro systems and phones with Sealife housing. Video recordings and still images served as the primary data source, as they allow for repeated observation and accurate identification of individuals over time. Still images were extracted from video footage or captured on-site to obtain high-resolution reference images for identification purposes.

Individual sharks were identified based on the notches on their dorsal fin, distinctive natural markings, and physical features.

All visual data was systematically reviewed after the dive, grouped by species, and where possible, manually linked to an existing individual. Using GIMP, photos of new individuals were cropped to the dorsal fin and divided into three sections, after which the notches on the dorsal fin were marked to obtain an accurate shark ID. This protocol allowed the recording of resightings of the individuals during different dives. To ensure consistency in identification, a standardized protocol was followed. Natasha Kelleher, a trained observer, reviewed all identifications. All individuals and resightings were recorded in a data sheet. The photos are stored in a shared Google Drive. While contributing to this database, a separate Excel spreadsheet was created to record these individuals and begin processing the human-related wounds (Figure 8).

3.2.4.2 Injury data processing

In order to assess injury occurrence in bull shark and blacktip shark populations, an extensive image-based analysis was conducted using data collected through the SharkWise Project. For the oceanic blacktip sharks, 25,354 photographs were taken and systematically reviewed and for the bull sharks, 3975 photographs. Each image was cross-referenced with the project's data sheet to ensure accurate identification using the assigned Shark ID. For every individual shark, all images within its designated personal folder were examined, alongside additional usable photographs available in the general archive going back to January 2020 on the project's Google Drive. For each shark the presence of retained fishing gear, jaw injuries, cuts and scars inflicted by fishing gear or vessel activity were recorded. The data was entered into an Excel database using separate tabs for each species (Figure 8).

During the analysis, the entire body of each shark was carefully inspected for the presence of anthropogenic injuries, with particular attention given to their location on the body. When a previously unrecorded injury was identified, it was documented as a new occurrence. These new injury records were further used to explore potential temporal patterns, including seasonal variation in injury frequency. The injury was linked to a season if found between the two dates delimiting this season.

Shark ID	Sex	Full body pictures	Injury present?	Number of injuries present	Type of injury 1	Placement injury 1	Season 1
2020120601	F	Yes	Yes	4	2	Mouth	N/A
2021031201	F	Yes	Yes	3	1	First dorsal	Summer
2021031801	F	Yes	Yes	2	1	First dorsal	Summer
2021031901	F	Yes	Yes	2	1	First dorsal	N/A
2021033101	F	No	No	0	N/A	N/A	N/A
2021033102	F	No	Yes	1	1	First dorsal	N/A
2021052001	F	Yes	Yes	6	3	Body	Summer
2021052002	F	No	Yes	1	4	First dorsal	N/A
2021092201	F	Yes	No	0	N/A	N/A	N/A
2021092202	F	Yes	Yes	2	1	Gills	N/A
2021101701	F	Yes	Yes	1	5	First dorsal	Spring
2021101801	F	Yes	Yes	2	1	Gills	N/A
2021101802	F	No	No	0	N/A	N/A	N/A
2021101803	F	Yes	No	0	N/A	N/A	N/A
2021101804	F	No	No	0	N/A	N/A	N/A
2021110501	F	Yes	Yes	1	1	First dorsal	N/A
2021110502	F	Yes	Yes	1	3	First dorsal	Spring

Figure 8: Overview of the injury recording database for Bull sharks.

3.2.5 Assessment protocol for anthropogenic injuries

Anthropogenic injuries were defined as any physical damage to sharks that could be directly or indirectly attributed to human activities, particularly fisheries and vessel traffic. Only injuries displaying clear diagnostic features consistent with such interactions were classified as anthropogenic, thereby reducing the likelihood of misclassifying naturally occurring injuries.

For each individual, the presence or absence of anthropogenic injury was recorded, followed by classification into distinct categories based on injury type. The five categories were defined as follows (Figure 9).

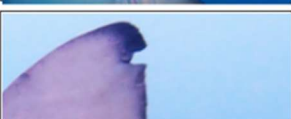
CATEGORY	INJURY EXAMPLES	
1. RETAINED FISHING GEAR AND ASSOCIATED CUTS, PERFORATIONS AND ABRASIONS		
2. JAW INJURIES		
3. PROPELLER-INDUCED TRAUMA		
4. AMPUTATIONS AND PARTIAL AMPUTATIONS LINKED TO FISHING GEAR		
5. AMPUTATIONS AND PARTIAL AMPUTATIONS LINKED TO VESSEL INTERACTIONS		

Figure 9: Injury categories with visualisations

3.2.5.1 Retained fishing gear and associated cuts, perforations and abrasions

This category includes visible fishing gear embedded in or attached to the animal, such as hooks, rope or metal leaders. These injuries range from superficially embedded hooks to deeply lodged gear associated with tissue deformation. Perforations and scars on the body caused by hooks were also included in this category. Some individuals have multiple hooks, perforations or scars with each occurrence recorded as a single incident. It further includes narrow, linear lesions associated with fishing line, often encircling the body, fins or mouth region. These marks were typically characterized by clean, sharp edges and in some cases showed signs of constriction or partial healing. This category does not include injuries on the mouth and jaws.

3.2.5.2 Jaw injuries

Injuries affecting the jaw structure were recorded separately due to their potential impact on feeding ability. These include perforations from hooks, retained hooks, deformation of the jaw and partial or complete fractures. Some sharks have multiple perforations or jaw injuries which will be recorded as single incidents.

3.2.5.3 Propeller-induced trauma

Parallel, evenly spaced lacerations or deep cuts consistent with vessel propeller strikes are recorded under this category. These injuries often appeared as repeated linear incisions with uniform spacing. This category also includes propeller scars and visible healed propeller wounds.

3.2.5.4 Amputations linked to fishing gear

This category includes severe traumatic injuries caused by fishing gear interactions, resulting in the partial or complete loss of external body structures or major structural damage. Injuries may involve amputations of fins (e.g., dorsal, caudal, pectoral, or pelvic fins), partial loss of the tail or other mutilations that impair swimming, maneuverability, balance or other essential functions. It also includes body parts that remain attached but are visibly broken or deformed due to entanglement, line tension, hooks or other fishing-related mechanisms.

3.2.5.5 Amputations linked to vessel interactions

This category includes severe traumatic injuries caused by collisions with or contact with vessels, resulting in the partial or complete loss of external body structures or major structural damage. Injuries may involve amputations of fins, partial loss of the tail or body sections, or other mutilations that could compromise swimming performance, stability or survival. It also includes body parts that are fractured or crushed following propeller strikes or other vessel-related trauma.

3.2.6 Reducing subjectivity in injury classification

Preventative measures were implemented to minimize observer bias and increase consistency in injury classification.

All individuals were assessed multiple times at different review stages to ensure consistency in injury detection and categorization.

Injury categories were defined prior to categorization using clear morphological descriptors to reduce uncertainty during classification.

A reference catalogue of observed injuries was compiled, including representative examples for each category. This catalogue serves as a visual standard for comparison and enables independent verification. This collection was assessed by a second trained observer.

When injury origin was uncertain, cases were excluded from the database to avoid overestimation.

3.2.7 Ethics and limitations

3.2.7.1 Ethical Considerations

This study was conducted using a strictly non-invasive, observational approach. At no stage of the study did physical interaction with sharks occur and no animals were handled, restrained or tagged. Data collection relied exclusively on visual observations during baited dives, thereby minimizing direct disturbance to the animals. Although bait was used to attract sharks to the study sites, this practice is a common and regulated activity within the Aliwal Shoal Marine Protected Area and was carried out in accordance with local guidelines. This method enabled consistent and replicable observations while avoiding physical injury to the species studied.

3.2.7.2 Limitations

When interpreting the results of this study, several limitations must be taken into account. First, the use of bait may introduce bias into the sample, as it may increase the local shark population. As a result, the observed aggregation patterns and interaction frequencies may not provide a complete account of natural conditions.

Second, environmental factors such as variable water visibility, lighting conditions and current strength may influence the detection rate and the accuracy of the photographs and observed wounds. In particular, reduced visibility may limit the ability to identify individuals. Finally, there is a risk that the same individuals were counted repeatedly, especially in cases where distinctive identification characteristics were absent or unclear, including additional or changing wounds over the years. This limitation is particularly relevant for population-level estimates and may lead to an overestimation of abundance. Efforts have been made to minimize this problem through the use of individual identification protocols; however, a certain degree of uncertainty remains. Given that a population database was used as the primary data source, certain sharks are not associated with full body pictures but only with fin identification images. This can cause an underestimation of the injuries found in sharks. To mitigate this problem, a representative sample was extracted.

3.3 Results and data processing

3.3.1 Data analysis bull sharks

3.3.1.1 Occurrence of anthropogenic injuries in bull sharks

A total of 53 individual bull sharks were assessed for the presence of anthropogenic injuries. Of these individuals, 28 sharks (53%) displayed at least one anthropogenic injury, while 25 sharks (47%) showed no visible anthropogenic injuries (Figure 10).

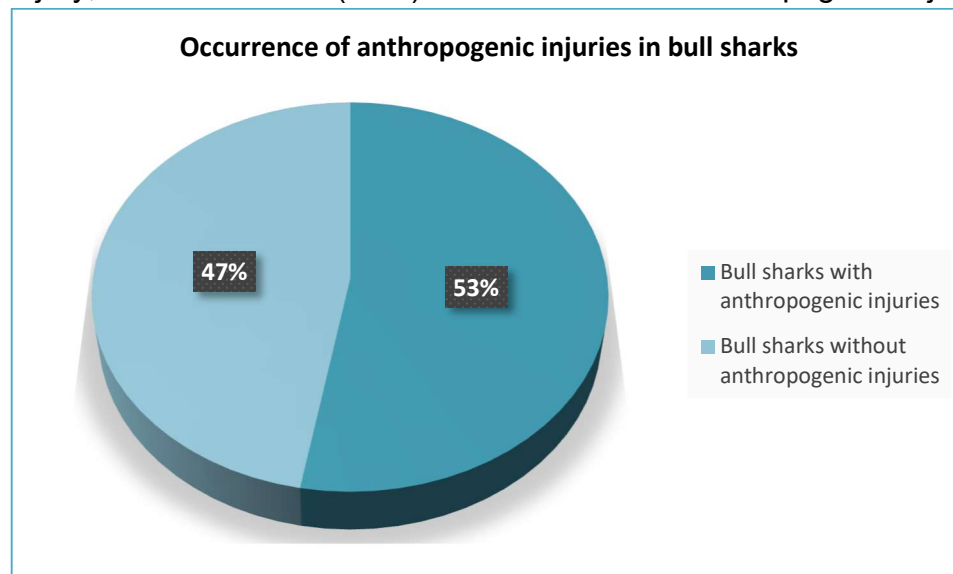


Figure 10: Occurrence of anthropogenic injuries in examined bull sharks (n = 53).

A total of 58 anthropogenic injuries were recorded among 28 injured bull sharks. Among the 28 injured individuals, variation was observed in the number of injuries recorded per shark (Figure 11). The majority of injured Bull sharks exhibited a single injury, representing 50% of the injured individuals (n = 14). Sharks with two injuries accounted for 21,4% (n = 6). Individuals with three and four injuries each represented 10,7% (n = 3 for both categories). Sharks with five and six injuries accounted for 3,6% (n = 1).

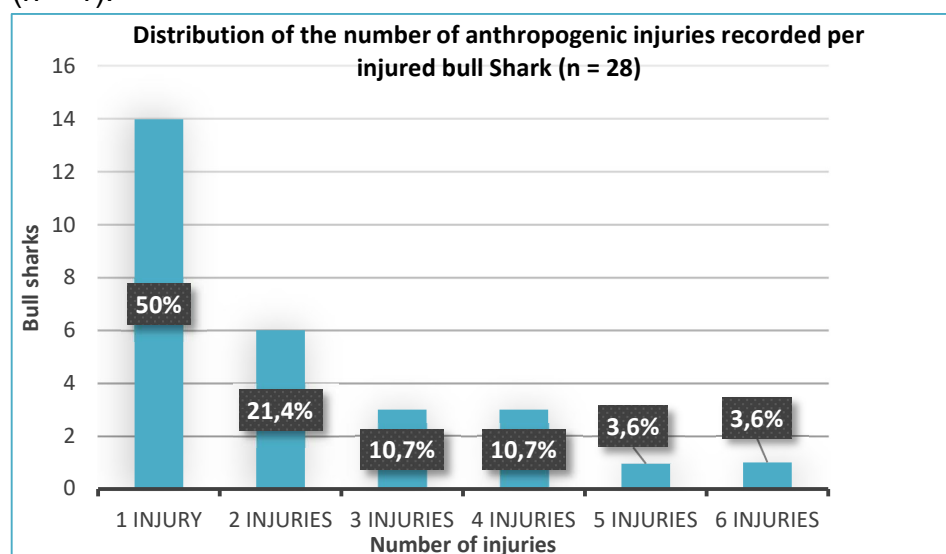


Figure 11: Distribution of the number of anthropogenic injuries recorded per injured bull shark (n = 28).

3.3.1.2 Types and characteristics of anthropogenic injuries in bull sharks

This section examines the 58 documented anthropogenic injuries found in 28 sharks. Percentage values are calculated based on total injuries rather than the total number of sharks examined. Injuries were classified according to their origin as either fishing-related or vessel-related (Figure 12). Fishing-related injuries accounted for 44 recorded injuries, representing 75,9% of all injuries. Vessel related injuries accounted for 14 injuries, corresponding to 24,1% of the total injuries recorded.

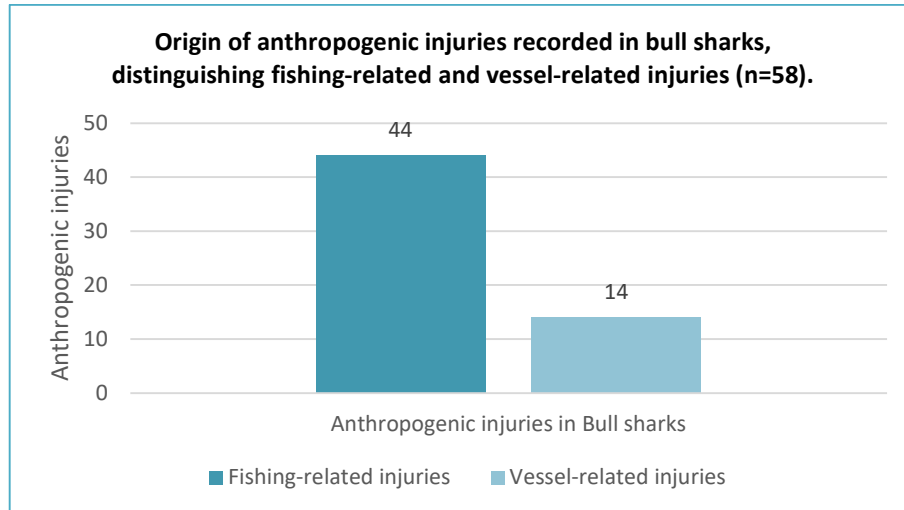


Figure 12: Origins of anthropogenic injuries recorded in bull sharks, distinguishing fishing-related and boat-related injuries (n = 58).

The recorded injuries were further categorized into five injury types (Figure 13). Type 1 injuries (Figure 9) were the most frequently observed injuries, accounting for 52% of all recorded injuries (n = 30). Type 3 injuries represented 22% (n = 13), while type 2 accounted for 19% (n = 11). Type 4 injuries represented 5% of the recorded injuries (n = 3), whereas Type 5 injuries were the least frequently observed category, accounting for 2% of all injuries (n = 1).

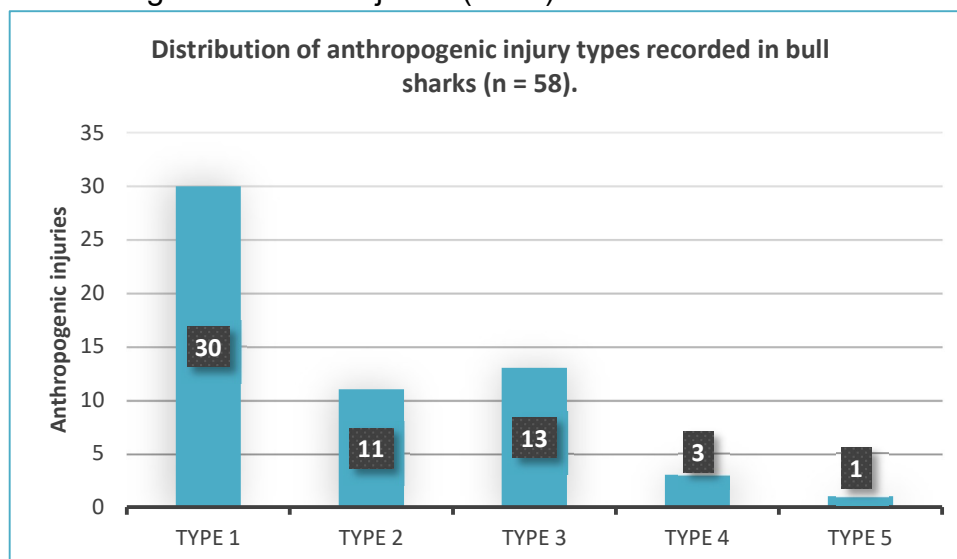


Figure 13: Distribution of anthropogenic injury types recorded in bull sharks (n = 58).

The anatomical distribution of injuries on bull sharks is presented in Figure 14 . Fins represented the most frequently affected body area, with 28 recorded injuries, corresponding to 48,3% of all injuries. Injuries located in the body accounted for 12 injuries (20,7%), while mouth injuries represented 11 injuries (19%). Gill injuries were the least frequently observed, accounting for 7 injuries (12,1%).

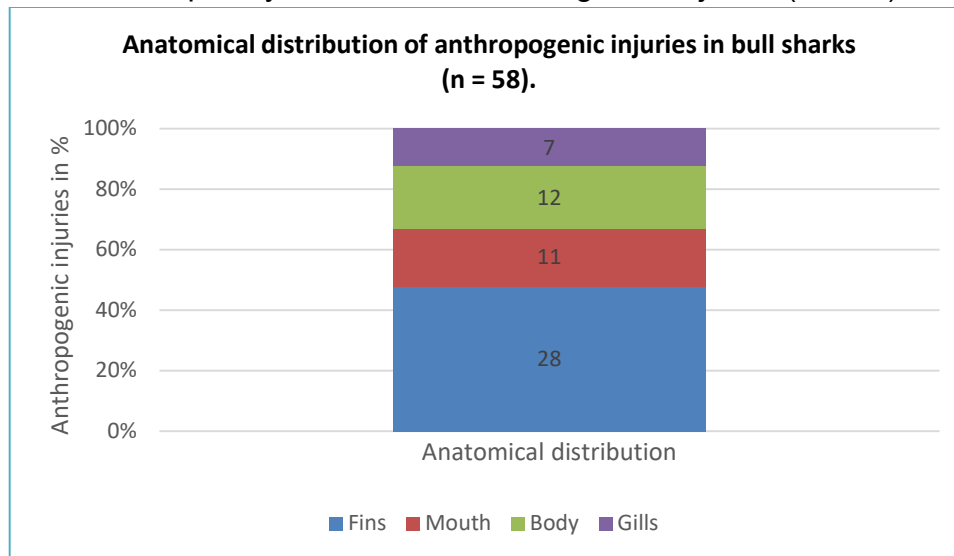


Figure 14: Anatomical distribution of anthropogenic injuries recorded in bull sharks (n = 58).

3.3.1.3 Seasonal variation in anthropogenic injury frequency in bull sharks

Seasonal variation in newly recorded anthropogenic injuries in bull sharks is represented in Figure 15. The highest number of newly recorded fishing- related injuries was observed during spring, with six injuries documented. One newly recorded vessel-related injury was also observed during this season. During summer, two newly recorded fishing-related injuries and two newly recorded vessel-related injuries were recorded. In autumn, three newly recorded fishing related injuries were observed, while no newly recorded vessel-related injuries were documented. No newly recorded anthropogenic injuries were observed during winter.

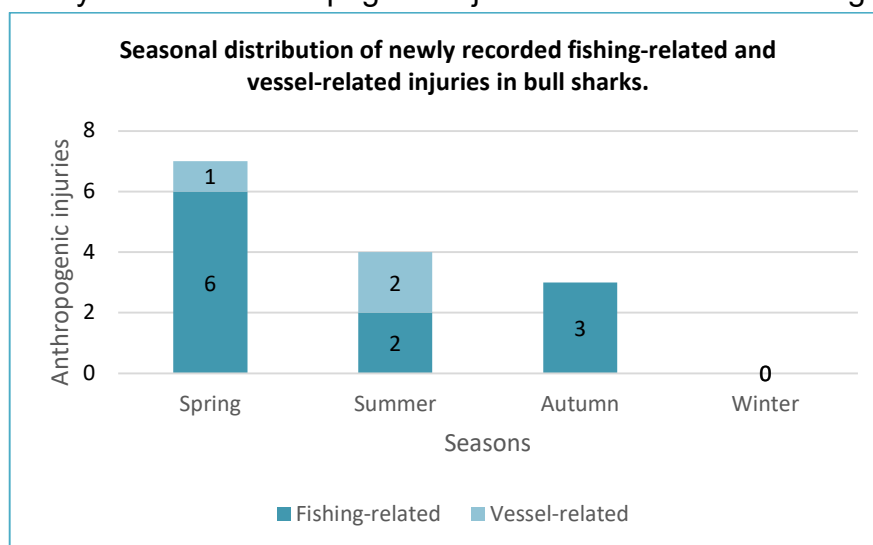


Figure 15: Seasonal distribution of newly recorded fishing-related and vessel-related injuries in bull sharks.

3.3.1.4 Completeness of photographic records in bull sharks

The completeness of photographic records was assessed for all examined bull sharks to evaluate the potential for underestimation of anthropogenic injuries. Of the 53 examined individuals, 28 sharks (53%) had full-body photographic records, whereas 25 individuals (47%) had incomplete photographic coverage (Figure 16).

Among the individuals with incomplete photographic records, anthropogenic injuries were recorded in 7 sharks (28%), while no visible injuries were documented in 18 sharks (72%). Incomplete photographic coverage may have limited the detection of injuries located on non-visible body regions.

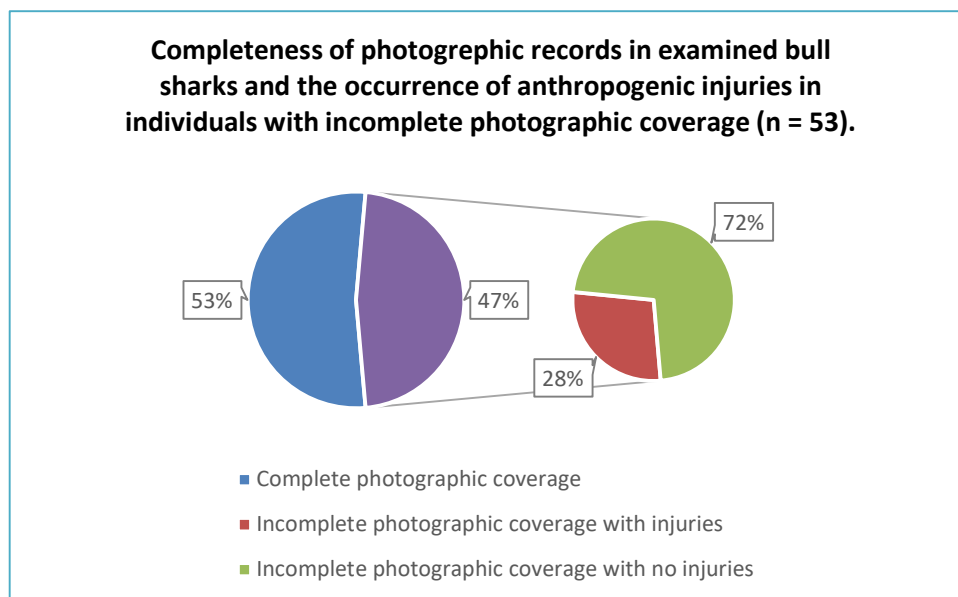


Figure 16: Completeness of photographic records in examined bull sharks and the occurrence of anthropogenic injuries in individuals with incomplete photographic coverage (n = 53).

3.3.2 Data analysis oceanic blacktip sharks

3.3.2.1 Occurrence of anthropogenic injuries in oceanic blacktip sharks

A total of 330 oceanic blacktip sharks were observed and assessed for the presence of anthropogenic injuries. Of these individuals, 175 sharks (53%) showed no visible anthropogenic injuries, while 155 individuals (47%) exhibited at least one anthropogenic injury (Figure 17).

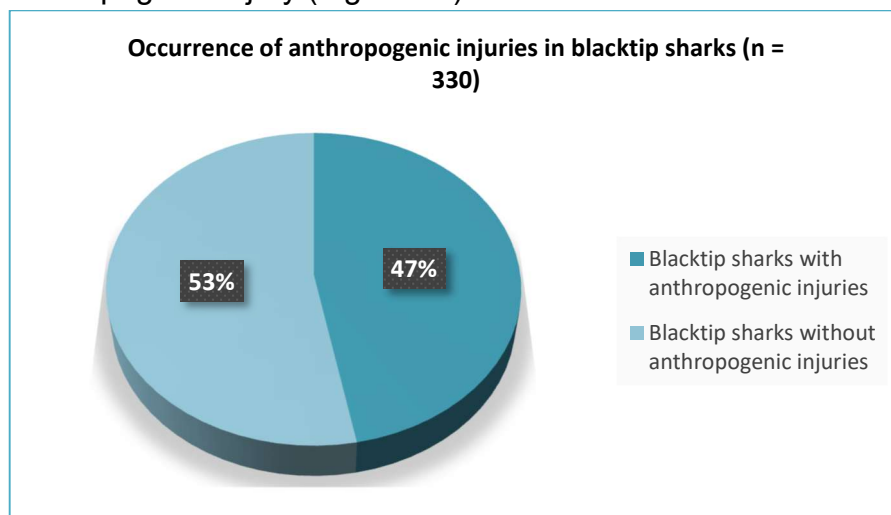


Figure 17: Occurrence of anthropogenic injuries in oceanic blacktip sharks (n = 330).

Within the 155 injured individuals, a total of 251 anthropogenic injuries were recorded. Among these 155 injured blacktip sharks, variation was observed in the number of injuries per individual (Figure 18). The majority of injured sharks exhibited a single injury, accounting for 63,9% (n = 99). Sharks with two injuries represented 20,6% (n = 32), while individuals with three injuries accounted for 9,7% (n = 15%). Sharks with four injuries represented 2,6% (n = 4), and sharks with five injuries accounted for 1,9% (n = 3). Individuals with six injuries were least frequently observed, representing 1,3% (n = 2).

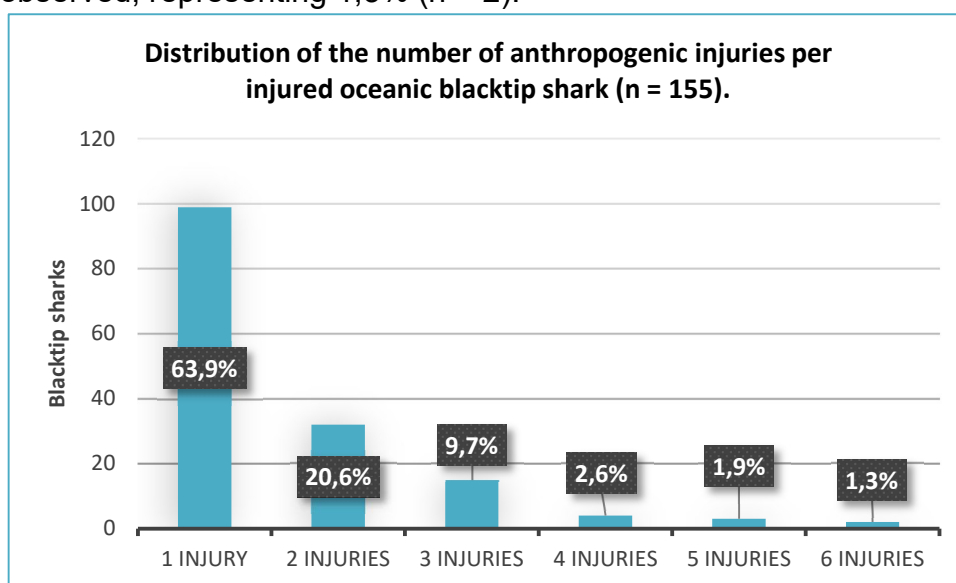


Figure 18: Distribution of the number of anthropogenic injuries per injured oceanic blacktip shark (n = 155).

3.3.2.2 Types and characteristics of anthropogenic injuries in oceanic blacktip sharks

A total of 251 anthropogenic injuries were recorded among 155 injured oceanic blacktip sharks from a total sample of 330 examined individuals. Percentage values are calculated based on total injuries rather than the total number of sharks examined. Injuries were classified according to their origin as either fishing-related or vessel-related injuries (Figure 19). Fishing-related injuries accounted for 152 recorded injuries, representing 60,6% of all injuries. Vessel-related injuries accounted for 99 injuries, corresponding to 39,4% of the total injuries recorded.

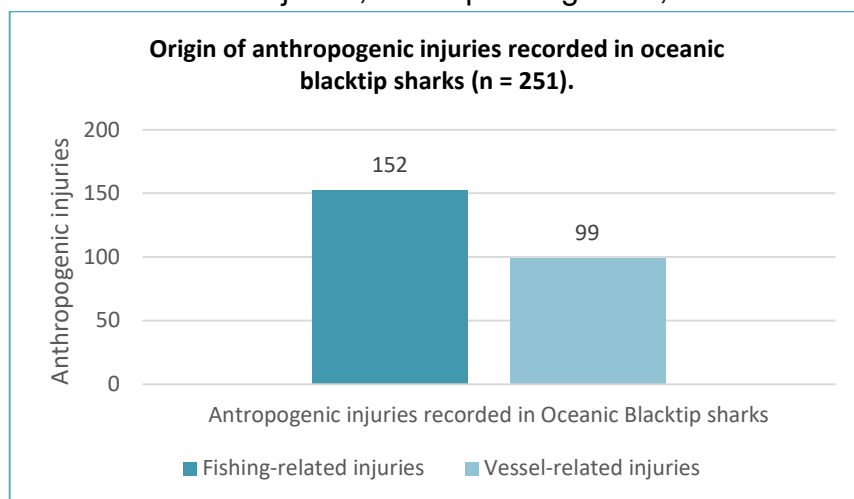


Figure 19: Origin of anthropogenic injuries recorded in oceanic blacktip sharks (n = 251).

The distribution of anthropogenic injury types is presented in Figure 20. Type 1 injuries were the most frequently observed category, accounting for 19% of all injuries (n = 123). Type 3 injuries represented 32,7% (n = 82), while Type 2 injuries accounted for 8,8% (n = 22). Type 5 injuries represented 6,8% (n = 17), and Type 4 injuries were the least frequent, accounting for 2,8% (n = 7).

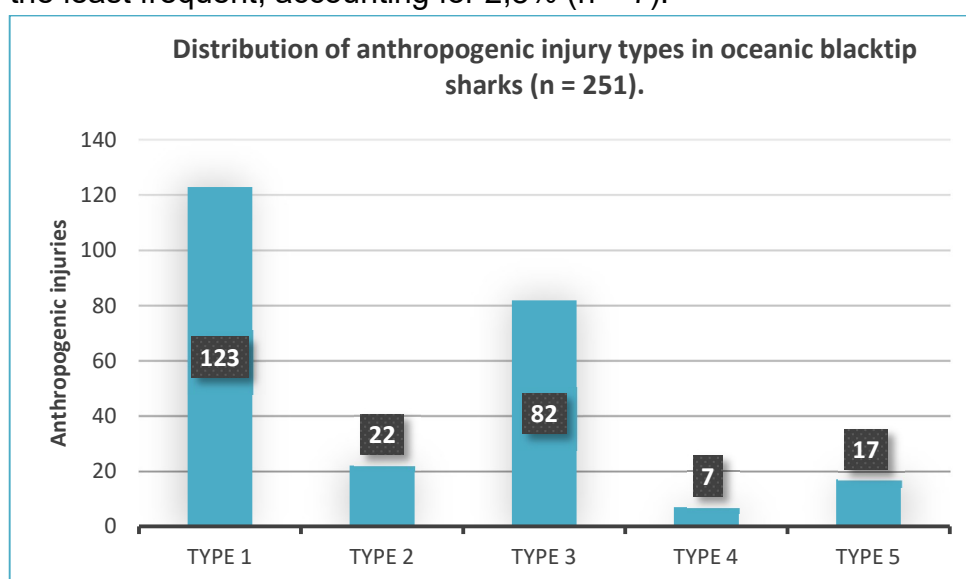


Figure 20: Distribution of anthropogenic injury types in oceanic blacktip sharks (n = 251).

The anatomical distribution of anthropogenic injuries in oceanic blacktip sharks is shown in Figure 21. Injuries affecting the fins were the most frequently observed, accounting for 154 recorded injuries (61,4%). Mouth injuries accounted for 27 injuries (10.8%), while body injuries represented 43 injuries (17,1%). Gill injuries were also observed in 27 cases (10,8%).

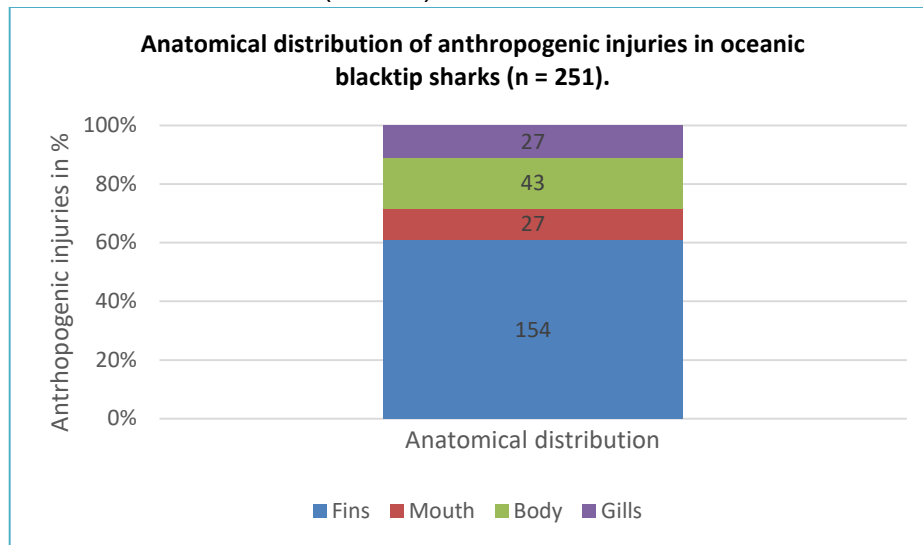


Figure 21: Anatomical distribution of anthropogenic injuries in oceanic blacktip sharks (n = 251).

3.3.2.3 Seasonal variation in injury frequency in oceanic blacktip sharks

Seasonal variation in newly recorded anthropogenic injuries in oceanic blacktip sharks is presented in Figure 22. In spring, a total of 5 newly recorded injuries were observed, consisting of 2 fishing-related and 3 vessel-related injuries. During Summer, 16 newly recorded injuries were observed, comprising 12 fishing-related and 4 vessel-related injuries. In autumn, 20 newly recorded injuries were observed, including 11 fishing-related and 9 vessel-related injuries. In winter, 11 newly recorded injuries were observed, consisting of 5 fishing related and 6 vessel-related injuries.

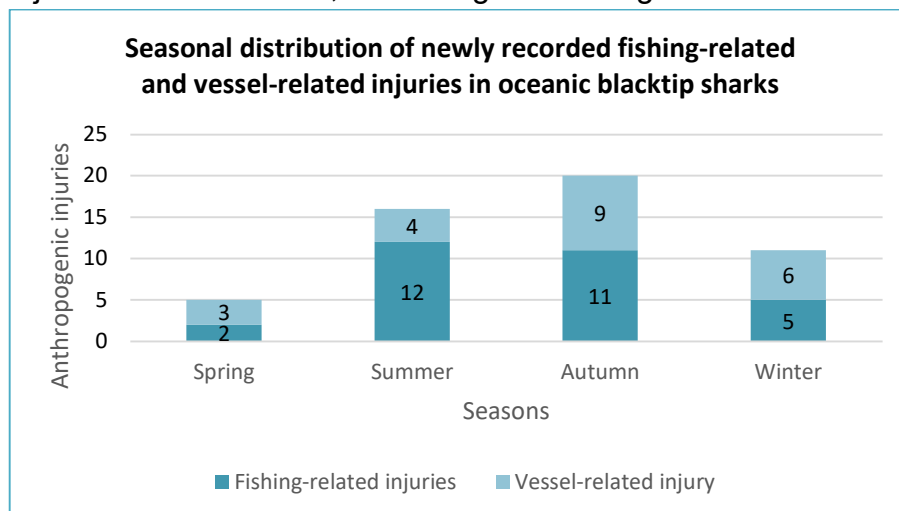


Figure 22: Seasonal distribution of newly recorded fishing-related and vessel-related injuries in oceanic blacktip sharks.

3.3.2.4 Image completeness of injuries in oceanic blacktip sharks

The completeness of photographic records was assessed for all 330 examined oceanic blacktip sharks to evaluate the potential for underestimation of anthropogenic injuries. Of the total individuals, 133 sharks (40,3%) had full-body photographic records, while 197 individuals (59,7%) had incomplete photographic coverage (Figure 23).

Among the individuals with incomplete photographic records, anthropogenic injuries were documented in 63 sharks (32%), while no visible injuries were recorded in 134 individuals (68%). Incomplete photographic coverage may have limited the detection of injuries located on non-visible body regions.

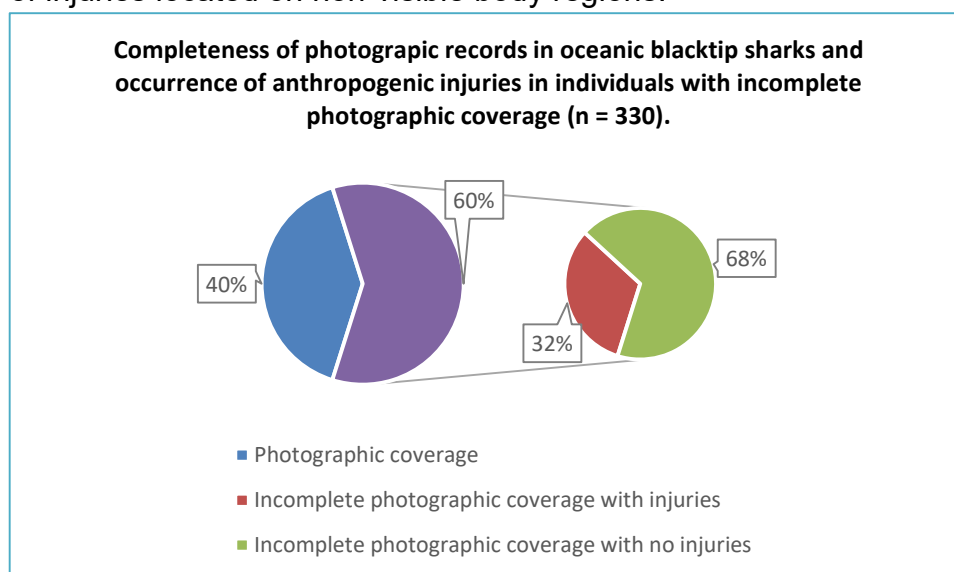


Figure 23: Completeness of photographic records in oceanic blacktip sharks and occurrence of anthropogenic injuries in individuals with incomplete photographic coverage (n = 330).

3.3.3 Comparison between species

3.3.3.1 Occurrence of anthropogenic injuries

A comparison of the occurrence of anthropogenic injuries between bull sharks and oceanic blacktip sharks is presented in Figure 24. Among bull sharks ($n = 53$), 28 individuals (52,8%) showed at least one anthropogenic injury, while 25 individuals (47,2%) showed no visible injuries. Among oceanic blacktip sharks ($n = 330$), 155 individuals (47%) exhibited anthropogenic injuries, while 175 individuals (53%) showed no visible injuries.

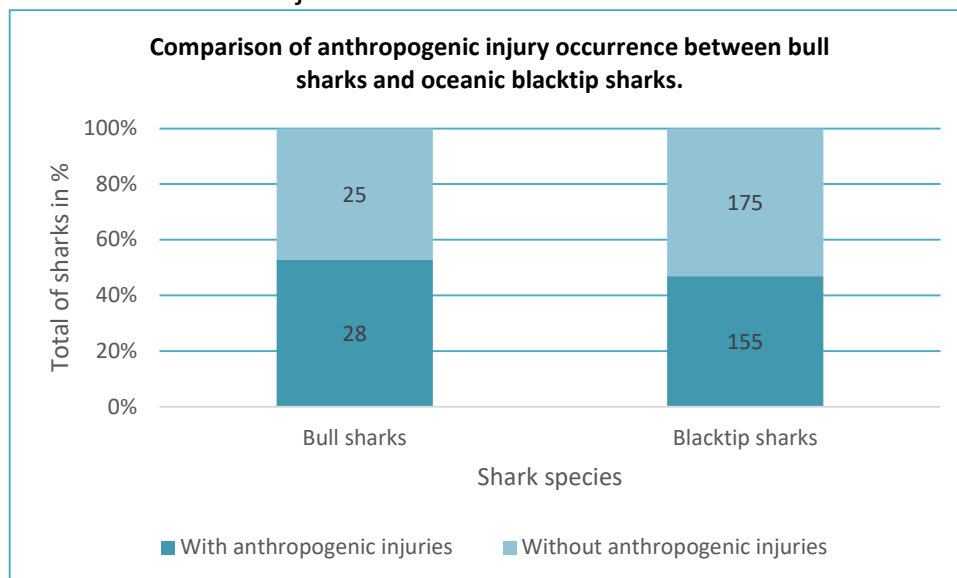


Figure 24: Comparison of anthropogenic injury occurrence between bull sharks and oceanic blacktip sharks.

The occurrence of anthropogenic injuries in both species (bull sharks and blacktip sharks) is presented in Figure 25. Among all 383 sharks, 200 sharks (52%) did not have anthropogenic injuries recorded while 183 (48%) showed at least one injury.

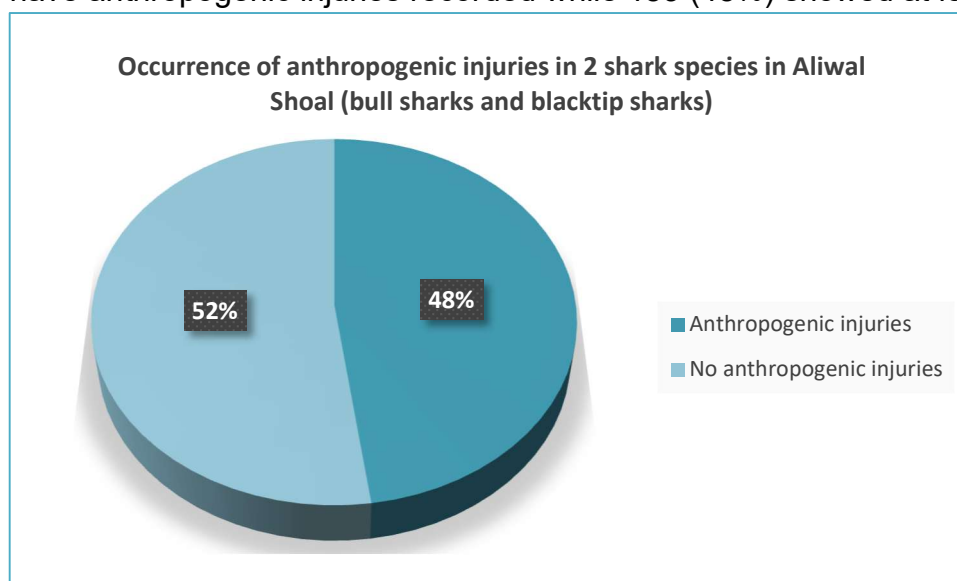


Figure 25: Occurrence of anthropogenic injuries in 2 sharks species in Aliwal Shoal (bull sharks and blacktip sharks, $n = 383$)

The distribution of the number of anthropogenic injuries per injured individual is represented in Figure 26. To allow direct comparison between species, values are expressed as proportions (percentage of injured individuals per species).

Among injured bull sharks (n = 28), 50% had one injury, 21,4% had two injuries, 10,7% had three injuries, 10,7% had four injuries, 3,6% had five injuries and 3,6% had six injuries.

Among injured oceanic blacktip sharks (n = 155), 63,9% had one injury, 20,6% had two injuries, 9,7% had three injuries, 2,6% had four injuries, 1,9% had five injuries and 1,3% had six injuries.

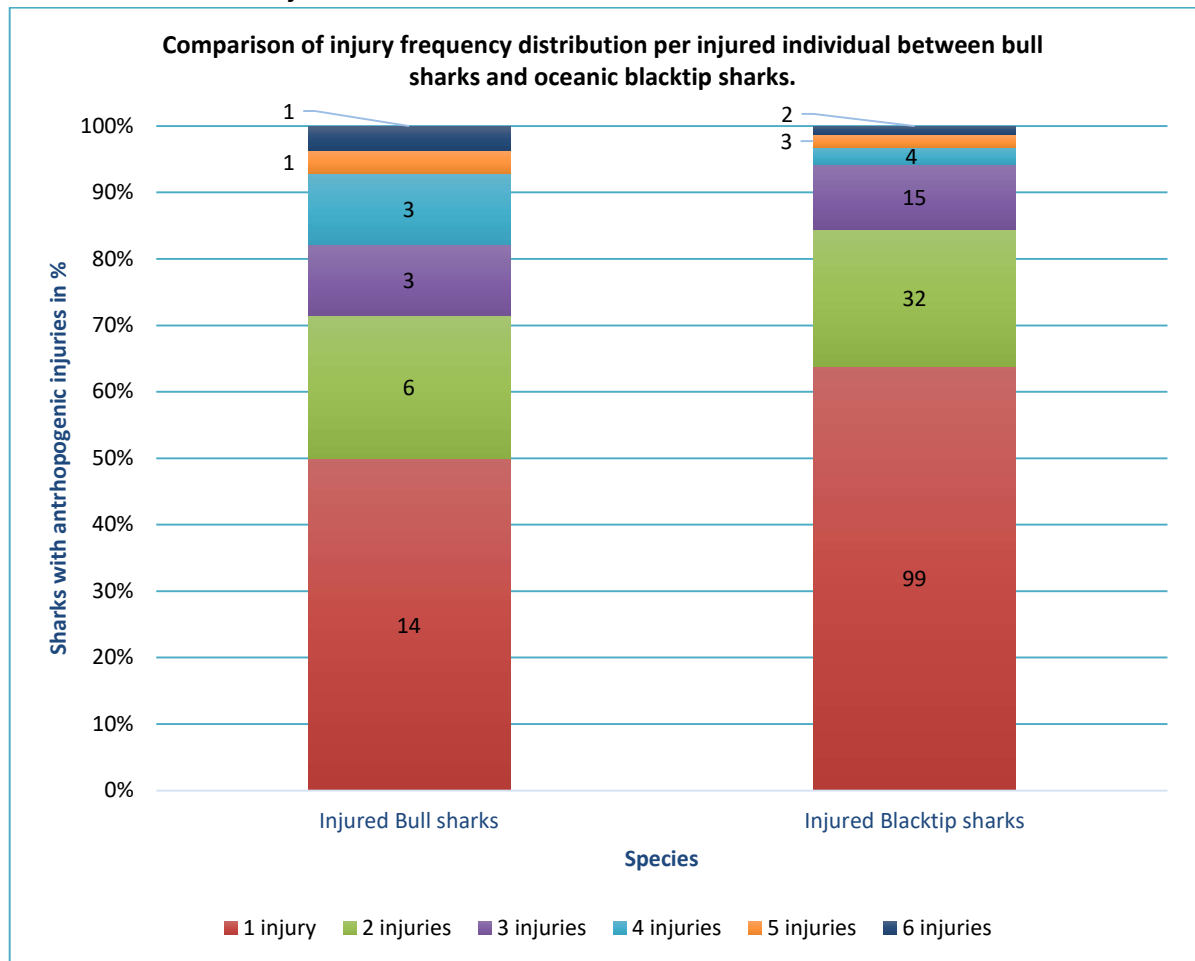


Figure 26: Comparison of injury frequency distribution per injured individual between bull sharks and oceanic blacktip sharks.

3.3.3.2 Types and characteristics of anthropogenic injuries

A comparison of the origin, type and anatomical location of anthropogenic injuries between bull sharks and oceanic blacktip sharks is presented in Figures 26-28. All values are expressed as proportions of total recorded injuries per species to allow direct comparison. This section is injury-based, n equals the total injuries per species, not individuals.

The origin of anthropogenic injuries differed between species (Figure 27). In bull sharks, fishing-related injuries accounted for 75,9% (n = 44) of all recorded injuries, while vessel-related injuries accounted for 24,1% (n = 14). In oceanic blacktip sharks, fishing-related injuries accounted for 60,6% (n = 152), while vessel-related injuries accounted for 39,4% (n = 99).

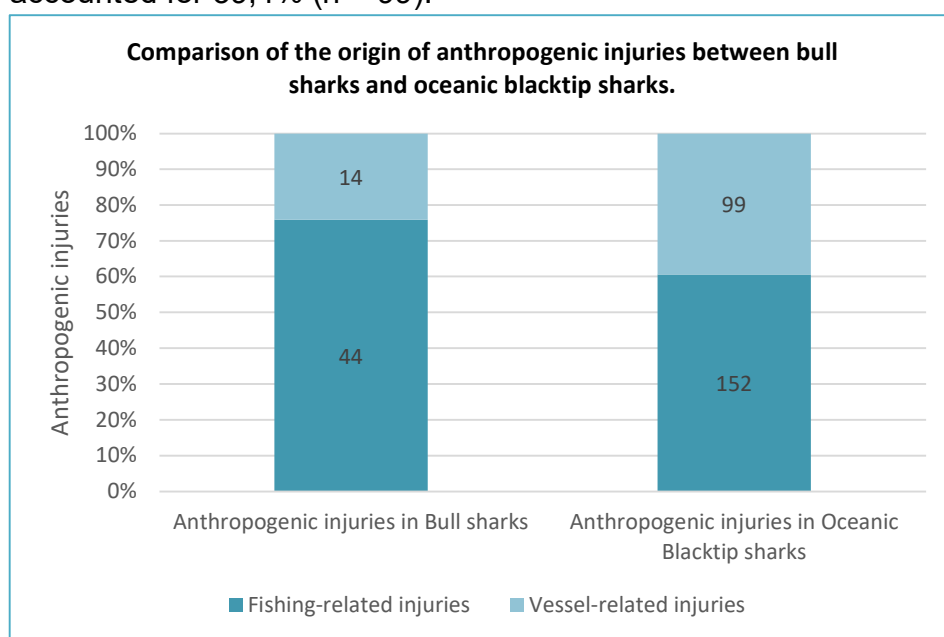


Figure 27: Comparison of the origin of anthropogenic injuries between bull sharks and oceanic blacktip sharks.

The distribution of injury types also varied between species (Figure 28).

In Bull sharks, Type 1 injuries represented 51,7% (n = 30), Type 2 represented 19% (n = 11), Type 3 represented 22,4% (n = 13), Type 4 represented 5,2% (n = 3) and Type 5 represented 1,7% (n = 1).

In oceanic blacktip sharks, Type 1 injuries accounted for 49% (n = 123), Type 2 for 8,8% (n = 22), Type 3 for 32,7% (n = 82), Type 4 for 2,8% (n = 7) and Type 5 for 6,8% (n = 17).

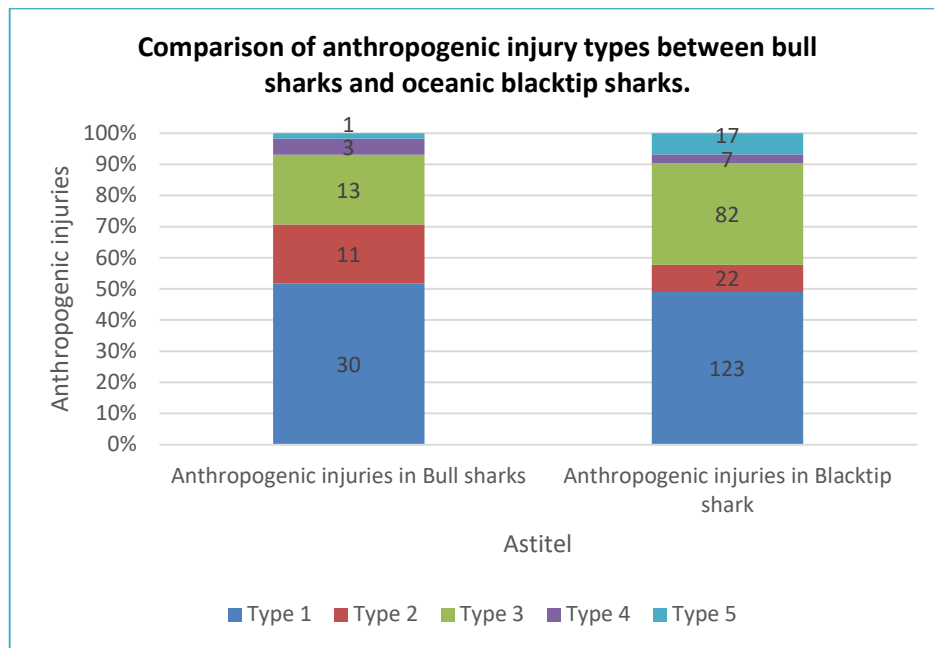


Figure 28: Comparison of anthropogenic injury types between bull sharks and oceanic blacktip sharks.

Differences were also observed in the anatomical distribution of injuries (Figure 29). In Bull sharks, fins were the most frequently affected body region, accounting for 48,3% (n = 28), followed by body (20,7%, n = 12), mouth (19%, n = 11) and gills (12,1%, n = 7).

In oceanic blacktip sharks, fins were also the most frequently affected region, accounting for 61,4% (n = 154), followed by body (17,1%, n = 43), and both mouth and gills (10,8% each, n = 27).

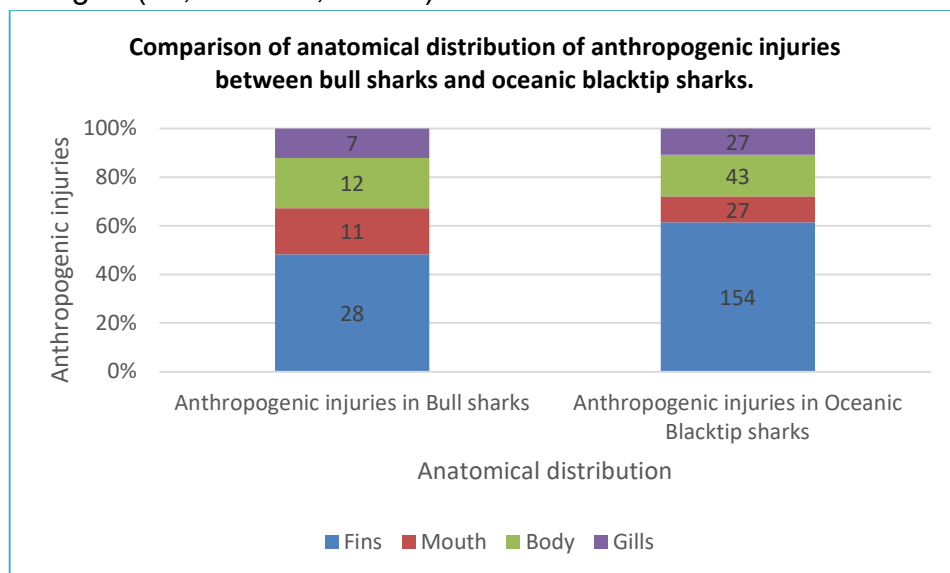


Figure 29: Comparison of anatomical distribution of anthropogenic injuries between bull sharks and oceanic blacktip sharks.

3.3.3.3 Seasonal variation in injury frequency

Seasonal variation in newly observed anthropogenic injury frequency is compared between bull sharks and oceanic blacktip sharks in Figure 30. Fishing-related and vessel-related newly observed injuries are shown separately for each species, with seasonal contributions (spring, summer, autumn, winter) expressed as proportions of total new injuries per category.

In bull sharks, newly observed fishing-related injuries showed seasonal variation, with higher proportions recorded in spring and summer compared to autumn and winter (Figure 30). Spring contributed the highest share, followed by summer, while autumn showed lower values and no new injuries were recorded in winter.

Vessel-related injuries in bull sharks also showed seasonal variation, with injuries recorded in spring, summer and autumn while no new vessel-related injuries were observed in winter (Figure 30).

In oceanic blacktip sharks, newly observed fishing-related injuries were recorded across all seasons. Summer and autumn showed the highest proportions, followed by winter, while spring showed the lowest contribution.

Vessel-related newly observed injuries in oceanic blacktip sharks were distributed across all seasons, with relatively similar contributions in spring, summer, autumn and winter (Figure 30).

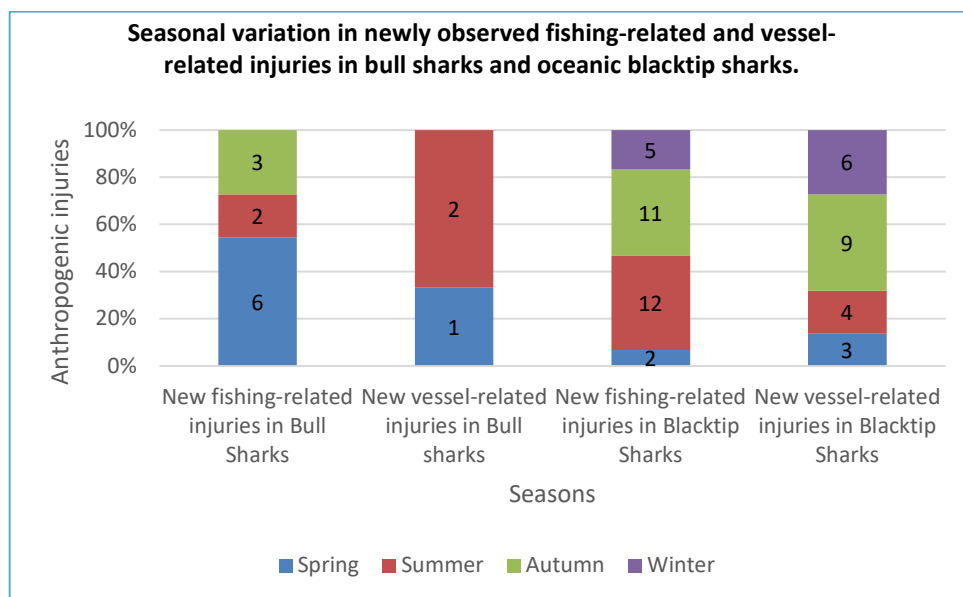


Figure 30: Seasonal variation in newly observed fishing-related and vessel-related injuries in bull sharks and oceanic blacktip sharks.

3.3.3.4 Completeness of photographic records in both shark species

The completeness of photographic records was assessed for all examined sharks (bull sharks and oceanic blacktip sharks combined, $n = 383$) to evaluate the potential underestimation of anthropogenic injuries. Of the total individuals, 161 sharks (42%) had full-body photographic records, while 222 individuals (58%) had incomplete photographic coverage (Figure 31).

Among individuals with incomplete photographic records, anthropogenic injuries were documented in 70 sharks (31,5%), while no visible injuries were recorded in 152 individuals (68,5%).

Incomplete photographic coverage may have limited the detection of injuries located on non-visible body regions.

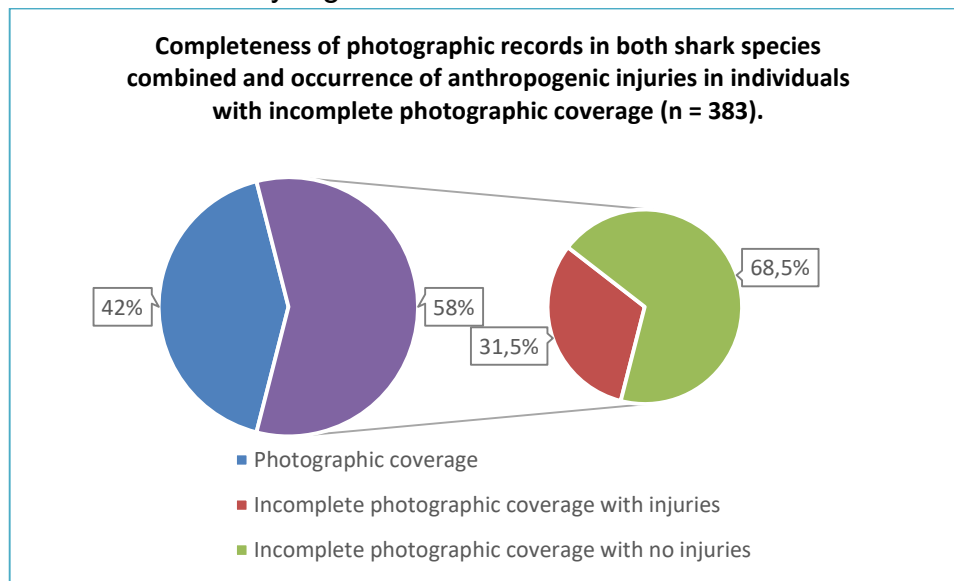


Figure 31: Completeness of photographic records in both shark species combined and occurrence of anthropogenic injuries in individuals with incomplete photographic coverage ($n = 383$).

3.3.4 Results summary

Overall, anthropogenic injuries were recorded in both bull sharks and oceanic blacktip sharks, with variation in occurrence, frequency and distribution. Fishing-related injuries were more prevalent than vessel-related injuries in both species. Injury types and anatomical locations showed broadly similar patterns, while seasonal variation in newly observed injuries differed between species and injury categories. Assessment of photographic completeness indicated that not all individuals had full-body coverage, which may have influenced injury detectability.

3.4 Discussion and interpretation of the results

3.4.1 Overview of findings

This study assessed anthropogenic injuries in bull sharks (*C. leucas*) and oceanic blacktip sharks (*C. limbatus*), focusing on injury occurrence, frequency per individual, injury type, anatomical distribution and seasonal variation. Anthropogenic injuries were recorded in both species, with fishing-related injuries consistently representing the majority of cases. Differences between species were observed in injury frequency distribution, seasonal variation and anatomical impact. Photographic completeness analysis indicated that incomplete visual records may have influenced injury detectability in both datasets.

3.4.2 Occurrence of anthropogenic injuries

The proportion of individuals exhibiting anthropogenic injuries was relatively similar between species, with slightly higher occurrence in bull sharks compared to oceanic blacktip sharks. This suggests that both species are regularly exposed to anthropogenic pressure. However, differences in sample size between species should be considered when interpreting these patterns.

The presence of injured individuals in both species indicates widespread interaction between sharks and human activities. These findings are consistent with previous studies (2.0. Literature review) reporting frequent shark exposure to fisheries and marine infrastructure in both coastal and pelagic environments.

3.4.3 Injury frequency per individual

Most sharks exhibited a single recorded injury, particularly in oceanic blacktip sharks. In bull sharks, a more even distribution across multiple injury categories was observed, with relatively higher proportions of individuals showing multiple injuries. These differences may reflect variation in exposure and habitat use. Bull sharks frequently inhabit coastal and estuarine environments, where repeated interactions with fishing gear and vessels are more likely. In contrast, oceanic blacktip sharks are more pelagic and their interactions may be more occasional or related to specific surface-associated activities.

3.4.4 Origin type and anatomical distribution of injuries

Fishing-related injuries were the dominant category in both species, indicating that fisheries represent a major source of anthropogenic impact. Vessel-related injuries were also recorded in both species, with relatively higher proportions in oceanic blacktip sharks compared to bull sharks.

Across both species, retained fishing gear and associated wounds were the most common injury type, suggesting frequent entanglement or interaction with fishing equipment. Propeller-related trauma and jaw injuries were also observed, indicating multiple anthropogenic mechanisms of injury.

The anatomical distribution of injuries indicates that anthropogenic interactions are not randomly distributed across the body but instead disproportionately affect functionally important regions. Fins were the most frequently injured structures in both species, likely due to their continuous exposure during locomotion and their role in propulsion and manoeuvrability. Injuries to fin tissue may therefore have direct implications for swimming performance, reducing efficiency, agility and potentially affecting escape responses and overall fitness, particularly in cases of repeated or severe damage.

Mouth and jaw-related injuries were also commonly observed. As these structures are essential for prey capture and feeding behaviour, damage in this region may interfere with feeding efficiency, prey handling and successful ingestion. Even partial impairment could have ecological consequences by reducing foraging success or increasing energetic costs.

Although less frequent, injuries affecting the gill region are particularly concerning due to their direct role in respiration and gas exchange. Damage in this area may compromise respiratory efficiency or increase susceptibility to secondary infection and physiological stress, which could have cascading effects on survival and condition.

Overall, the concentration of injuries in locomotory, feeding and respiratory structures suggests that anthropogenic interactions have the potential to affect key functional systems in sharks. This highlights that beyond simple occurrence, anthropogenic injuries may have biologically meaningful consequences for individual performance and fitness, even if the exact severity of these effects cannot be quantified from observational data.

3.4.5 Seasonal variation in injury frequency

Seasonal variation in newly observed anthropogenic injuries was based on the recorded month of observation and grouped into seasonal categories. Differences in seasonal distribution were observed between species and injury origins.

Fishing-related injuries occurred across multiple seasons in both species, with relatively higher proportions during warmer periods. Vessel-related injuries showed more variable seasonal patterns and were less consistently distributed throughout the year.

These patterns may reflect seasonal changes in both environmental conditions and human activity. Bull sharks, which frequently inhabit estuarine and coastal environments, may experience increased exposure to fisheries and vessel traffic in areas of concentrated human activity. Oceanic blacktip sharks, being more pelagic but surface-oriented, may be more frequently observed during surface-based activities such as recreational diving and ecotourism.

Seasonal ecological events, such as the sardine run, may further increase spatial overlap between sharks, prey aggregations, fisheries and ecotourism activities. However, as this study is based on observational data, such relationships remain speculative.

Overall, seasonal variation in newly observed injuries likely reflects a combination of ecological behaviour and variability in human activity rather than a single driving factor.

Aliwal Shoal is a well-established ecotourism and shark diving site, where observational effort is likely to vary throughout the year. Seasonal fluctuations in tourism and diving activity may influence the probability of shark encounters and injury detection for both species. This may be particularly relevant for oceanic blacktip sharks, which are more surface-associated and therefore more likely to be observed during surface-based diving activities.

Therefore, seasonal variation in newly observed injuries in both bull sharks and oceanic blacktip sharks likely reflects a combination of species-specific habitat use, seasonal environmental conditions and variability in human activity, including fisheries pressure and ecotourism effort across the defined seasonal periods.

3.4.6 Photographic coverage and detection bias

Photographic analysis revealed that a substantial proportion of individuals in both species lacked full-body coverage. Among these individuals, a notable proportion showed visible injuries, suggesting that incomplete photographic records may have led to underdetection of anthropogenic injuries.

This limitation highlights a potential bias in injury assessment, particularly for body regions not visible in partial imagery. As a result, the recorded injury frequencies should be considered conservative estimates.

3.4.7 Limitations and methodological considerations

Several limitations should be acknowledged. Differences in sample size between species may influence proportional comparisons. In addition, reliance on photographic records limits injury detection to visible body regions, potentially underestimating true injury prevalence. Classification of injury type and origin is also based on visual interpretation and may involve some uncertainty.

Despite these limitations, the dataset provides a structured comparison of anthropogenic injury patterns across two ecologically distinct shark species.

3.4.8 Ecological implications

The results indicate that anthropogenic interactions are widespread across both coastal and pelagic shark species. The dominance of fishing-related injuries highlights fisheries as a major source of anthropogenic impact. Differences between species likely reflect variation in habitat use and behavioural ecology, which influence exposure to human activities.

Understanding these patterns is important for improving knowledge of shark–human interactions and informing conservation strategies aimed at reducing anthropogenic impacts in marine ecosystems.

4 Conclusion

This study highlights the impact of anthropogenic pressures and examined anthropogenic injuries in bull sharks (*C. leucas*) and oceanic blacktip sharks (*C. limbatus*) at Aliwal Shoal, Umkomaas. The research focused on injury occurrence, frequency, type, anatomical distribution and seasonal variation, as well as the influence of photographic coverage on injury detection.

Anthropogenic injuries were recorded in both species, indicating regular exposure to human-related impacts in the study area. Fishing-related injuries were the most dominant category in both species, followed by vessel-related injuries, highlighting fisheries as the main source of anthropogenic interaction. Injury types and anatomical distribution were broadly similar between species, with retained fishing gear and fins being the most frequently affected category and body region.

The concentration of injuries in key anatomical regions such as fins, jaws and gills suggests that anthropogenic interactions may affect structures essential for locomotion, feeding and respiration. This indicates that beyond their frequency, these injuries have the potential to impact important functional processes that are critical for survival and ecological performance.

Differences between species were observed in injury frequency per individual, with oceanic blacktip sharks more often showing a single injury and bull sharks displaying a more even distribution across multiple injuries. Seasonal variation in newly observed injuries suggested differences in temporal patterns, likely influenced by ecological factors and human activity, including fisheries and ecotourism at Aliwal Shoal.

Incomplete photographic coverage likely resulted in underdetection of some injuries, indicating that reported values are conservative estimates.

Overall, the results demonstrate widespread anthropogenic interaction with sharks in the study area and highlight the importance of improved monitoring to better understand and manage human impacts on shark populations.

Concluding remarks

Writing this bachelor's thesis and completing my internship in South Africa has been an extremely valuable and educational experience, both academically and personally. Throughout this process, I gained a deeper understanding of shark ecology, anthropogenic impacts on marine species and the importance of scientific research in marine conservation.

One of the most important skills I developed during this project was learning how to work systematically with large datasets and photographic analyses. Reviewing thousands of photographs required patience, precision and consistency. I also learned how to organise, analyse and interpret scientific data in a structured way, while critically reflecting on the reliability and limitations of the collected information.

In addition, this bachelor's thesis helped me improve my scientific writing and communication skills in English. Writing a complete scientific report taught me how to present results objectively, interpret findings critically and translate complex information into a clear text. I also became more confident in working independently and managing a research project from beginning to end. Overall, this bachelor's thesis has not only expanded my scientific knowledge but has also strengthened my practical and personal skills, which will be valuable in my future academic and professional career.

Working with sharks in their natural environment at Aliwal Shoal further broadened my perspective on marine conservation and the impact of human activities on wildlife. Observing these animals increased my appreciation for marine ecosystems and strengthened my motivation to contribute to their protection in the future. During this project, I also became more aware of the growing need for conservation research to better understand the impact of human activities on marine ecosystems and vulnerable shark populations. I hope that continued cooperation between researchers, conservation organisations, local communities, ecotourism operators and fisheries will contribute to more effective protection and management strategies in the future. Working together and sharing knowledge will be essential to ensure the long-term conservation of sharks and the marine environments they inhabit.

Finally, this experience taught me the importance of collaboration within scientific research and conservation. Receiving guidance, feedback and support from supervisors, researchers, and friends showed me how valuable teamwork and shared expertise are in producing reliable scientific work.

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