

A Review of Shark Attacks in the Sydney Region

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Post: May 2015.

Introduction: This paper will review unprovoked shark attacks in the Sydney region in relation to possible contributing factors including discharged pollution from abattoirs, sewage and rubbish into Sydney Harbour and Sydney ocean beaches from 1852-2014.

Shark attack records for the Sydney region from 1852-2014 totalled 83 unprovoked cases (see Table 1). The review will look at two distinct Sydney regions 1.) Sydney Harbour (estuaries, creeks and rivers), and 2.) Sydney ocean beaches.

This paper will discuss the potential impacts on shark behaviour from 1.) Direct discharge into the harbour from large abattoir operations (offal and other by-products) and urban sewage, 2.) Dumping of rubbish, sewage and offal into the ocean off Sydney heads by barge, and 3.) Discharge of sewage and abattoir by-products via the ocean outfalls along the coast of Sydney. The review will also look at possible effects on shark behaviour due to changes to Sydney Harbour ecosystems related to estuarine habitat reclamation and industrial pollution.

Methods: The Australian Shark Attack File (ASAF) includes 970 cases of provoked and unprovoked shark incidents in Australian waters from 1791 to 2014. Of these 98 unprovoked attacks occurred in the Sydney region from Palm Beach in the north to Port Hacking in the south including the estuaries, rivers and creeks in Sydney Harbour, Botany Bay and Port Hacking from 1852-2014. The paper examines unprovoked shark attacks excluding 15 cases involving Wobbegong sharks (*Orectobolus sp.*). Wobbegong Shark bites tend to be as a result of a defensive reaction by the shark to people inadvertently getting too close or stepping on them.

Sydney Harbour pollution sources:

Since colonisation (1871) until the mid 1900s urban sewage, council rubbish, abattoir by-products (blood, offal, etc) and industrial pollutants were discharged directly into Sydney Harbour.

During the period 1852–1988 two large abattoirs were in operation in Sydney Harbour – Glebe Island Abattoirs (1852-1915) and Homebush Abattoirs (1916-1988). Both abattoirs had a long history of discharging their by-products directly into the harbour. In 1923 the Homebush Abattoir was the biggest of its kind in the Commonwealth employing up to 1600 staff with a capacity to slaughter 18,000 to 20,000 sheep, 1,500 cattle, 2,000 pigs and 1,300 calves a day (Industrial History, 2014).

From the late 1800's it was suggested that the cause of increasing number of sharks in Sydney Harbour could be from blood and offal from abattoirs, sewage that discharged directly into the harbour, the dumping of rubbish, sewage, and offal off Sydney heads and the discharge of sewage and by-products from abattoirs via the ocean outfalls (SMH, various dates).

There are many anecdotal reports from a variety of sources including shark experts, professional fishermen and the general public of increased shark activity in Sydney Harbour since the early days of the abattoirs operations in the mid 1800's. Articles and letters to the editor in Sydney newspapers reported or more often complained of the pollution from the blood and offal being discharged directly into Sydney Harbour that lead to extensive algal blooms and clogged some estuaries with offal, sewage and other rubbish (SMH, 1879). In the 1930s algal blooms were abundant in Homebush Bay due to the increase in nutrients derived from the dumping of waste material from carcasses. Offal and sewage regularly washed up along the harbour foreshores and beaches (SMH, various dates).

Abattoir sourced offal, urban sewage and council rubbish was regularly dumped into the ocean off Sydney Harbour heads for many years and also washed up on ocean and harbour beaches and was a constant source of complaints from residents around the harbour foreshores and coastal communities for over 100 years (SMH, various dates).

Three major ocean outfalls were built around Sydney to discharge sewage into the ocean. The first of these ocean outfalls was commissioned at Bondi in 1889, followed by Malabar in 1916, and North Head in 1930.

Initially these 3 ocean outfalls discharged sewage and offal close to the shoreline resulting in more complaints about the discharged sewage and offal washing up on local ocean beaches (especially those beaches close to the outfalls around Bondi, Maroubra and Manly). To address the pollution concerns sewage pre-treatment plants were commissioned for Malabar in 1959 and North Head in 1972. All three outfalls were extended 3-5 kilometres off shore between 1984 and 1992 "considerably improving water quality at Sydney's beaches" (Sydney Water, 2014).

Increasing urbanisation and reclamation of Sydney Harbour shoreline also impacted on the harbour water quality and biodiversity. Since colonisation the reclamation of the harbour's shoreline has reduced the estuarine area by over 22%. Approximately 50% of the harbour foreshore is now composed of retaining seawalls or other built habitats. Retaining sea walls affect the distribution and abundance of intertidal organisms by replacing gently sloping muddy, mangrove and saltmarsh wetlands (Birch, 2007; Birch, *et al.* 2008; Reid, *et al.* 2010).

Sydney Harbour also housed many industries which discharged directly into the harbour (industries included ship building and maintenance, metal foundries, tanneries, whale oil processing, sugar works, distillery kerosene refinery, sawmills and breweries to name a few) as well as stormwater runoff from roads, etc. It was not until the 1970's when the State Pollution Control Commission was established that the discharge of toxic substances into the harbour and the sewage system was restricted (Beder, 1992).

Accumulation of toxic chemicals in the sediment of Sydney Harbour has been estimated to have affected around 25% of the harbour with a probability of being toxic to an intermediate level (~50%) (Birch, *et al.* 2008). The marked changes in habitat in these areas has resulted in major alterations in ecological function, as well as biological productivity and changes in the hydrological and physio-chemical attributes of the intertidal zone (Birch, 2007).

As a precautionary measure Sydney Harbour was closed to commercial fisheries in 2006 because of heavy metal contamination in some parts of the harbour. However, fish captured from Sydney Harbour by recreational fishers has not been banned and fishermen are urged to follow dietary advice on the consumption of seafood from the Harbour, Parramatta River and other connected tidal waterways (NSW DPI, 2014).

Possible influences on shark behaviour:

According to Reid, *et al*, (2010) Sydney Harbour has recorded over 3,000 marine species (includes 586 species of fish) which is more than any other harbour. It is two to three times greater than the neighbouring Botany Bay, Port Hacking or the Hawkesbury River regions. This figure does not include the many marine birds, marine mammals (whales, dolphins & seals), turtles and the many invertebrate groups (especially sponges and corals) that also inhabit or visit its waters (Humphreys, 2013).

Estuaries provide a highly dynamic environment where marine species distribution and abundances are often a result of interaction between complex physical (e.g. temperature, salinity, turbidity, tidal movements) and biological processes (e.g. reproduction, mating and feeding). Estuaries, mangroves, rivers, and creeks are prime breeding, development and feeding grounds for fish and invertebrate species and for the larger predatory fish and sharks that live in or visit the harbour.

Additional food source (food provisioning) was prevalent from the discharge into the harbour of rubbish and sewage (1800's to early 1900's), abattoir operations (1852-1988) and whaling operations from 1892-1938 (SMH, 2012). As an example - in 1902 a Parliamentary report stated that "cleaners hauled from Sydney Harbour between January – June of that year 1,957 rats, 784 cats, 968 dogs, 225 bags of meat, two bags of fish, 1,150 fowls, 25 parrots, 19 sheep, 11 pigs, one bullock, five calves, three flying foxes, two goats, two sharks, 118 rabbits and 10 bags of chaff." (Johnston, 2008). This 6 month report illustrates the compounding pollution and food provisioning source in the harbour during the late 1800's and early 1900's.

Free swimming predatory sharks are attracted to naturally occurring food sources (such as schooling fish) but are also attracted to artificially supplied food items (food provisioning). This is demonstrated most clearly when 'chum' or 'berley' is used to attract sharks to fishing and cage diving boats. Large amounts of chopped up fish mixed with blood and fish oil is poured into the sea and pieces of fish hung around boats is commonly used. There are many examples of shark feeding dive tours where sharks are attracted to, and feed on, large ball of fish pieces as SCUBA divers observe from a distance.

A newspaper article in 1901 reported that 'it has been stated that the establishment of the abattoirs on the island (Glebe Island) and the discharge of offal into the harbour, were among the chief causes of Port Jackson (Sydney Harbour) becoming infested with sharks' (The Sydney Mail, 1901). In 1931 another newspaper article warned of 'man eating whalers in Port Jackson' (SMH, 1931). In the early 1950's Auburn Council erected a sign at the nearby Silverwater baths 'Danger – Polluted Water – Sharks'. The baths were near the Silverwater Bridge and sharks were attracted there by effluent released into the river by the State Abattoirs (Industrial History, 2014).

Observations of Tiger Sharks and other large sharks being attracted to the ocean outfalls and feeding directly (on offal) or indirectly (attracted to fish congregating around sewage outfalls) was noted by several contributors in the submissions to the Report of the Shark Menace Advisory Committee (1935) when they considered various methods to reduce the incidence of shark attacks off Sydney. They suggested that large sharks were attracted to the ocean outfall points to feed on items being discharged and on the fish that congregate around the discharge points. Dr John Paxton (an eminent Ichthyologist at the Australian Museum) also attributed the increase in the number of large free swimming sharks in the Sydney region to their attraction to discharged blood and offal from abattoirs through the ocean outfall at Malabar from 1916 -1970 (Paxton, 2003).

Research into food provisioning in sharks found that it can affect the behaviour, physiology and health of sharks. A study of Bull Sharks (*Carcharhinus leucas*) being hand fed in Fiji (Brunnschweiler and Barnett, 2013) noted that the sharks were attracted to the feeding sites and remained for longer periods of time on feeding days but left the area when feeding stopped. Amongst the detrimental effects of food provisioning was that the long-term aggregation of sharks can modify the natural behaviour of the animals, potentially increase their aggression toward humans. Intra and interspecific aggression was also witnessed in several studies, leading to an increased risk of potentially severe bites to humans (Clua, *et al.* 2010).

A study of cage diving activities in the Neptune Islands (South Australia) also found that food provisioning did attract White Sharks (*Carcharodon carcharias*) and did change their swimming behaviour (Huveneers, *et al.* 2012). They found the sharks were spending more time in close proximity to the berley source and at the surface in proximity to the teaser baits hung around the cage or diving boats.

Shark attacks in the Sydney region:

Between 1852 - 2014 there were a total of 83 unprovoked shark attacks in the Sydney region (excluding Wobbeong shark bites) including 40 fatalities (last fatality being recorded in 1963). During this time the population of Sydney increased from 25,000 to 4,500,000 people (see Table 1).

Table 1. Shark attacks in the Sydney Region (including coastal beaches and harbour) 1852 to 2014.

Abattoir Operations	Period	Shark Attacks (Fatal) Sydney Region			Sydney Population*
		Sydney Harbour	Ocean Beaches	Total	
Glebe Island	1852 – 1915	24 (15)	3 (1)	27 (16)	25,000 – 810,000
Homebush	1916 – 1988	12 (9)	30 (15)	42 (24)	849,000 – 3,830,000
No abattoirs	1989 – 2014	7 (0)	7 (0)	14 (0)	3,850,000 - ~ 4.5 million

* (Kelly, 2015)

All but 2 shark attack cases recorded in the Sydney region occurred between the months of November to April. The period from November to April each year coincides with the arrival of the East Australian Current moving warmer water south as it travels down the east coast of Australia. This period also includes the school, Christmas and New Year holidays for the people of Sydney. This 5 month period of maximum use of beaches, harbours and rivers for recreation is also the time when most people are in the water (summer period). However, swimming during daylight at beaches was not legal in Australia until 1904 (West, 2011).

In Sydney Harbour there were 43 shark attack cases recorded over the review period (1852 - 2014) and all but one case has been attributed to the Bull Shark (*C. leucas*) (see Table 1).

Since 1964 to 2014 there have only been 7 unprovoked shark attacks recorded in the harbour. No injuries were reported in 4 cases involving bites or bumps to small water craft (2 x rowing scull, surf ski & kayak). In two cases swimmers received only minor injuries (teeth marks) one was swimming late at night (01:00) across the Parramatta River and the other was swimming through a school of baitfish and was bitten on the knee.

The case of a Navy diver bitten in February 2009 involved diving in Sydney Harbour in murky water early in the morning and testing sonar and diver detection devices. The sonar and diver detection devices may have attracted the shark to the area. However, large schools of fish had been reported in this location (and the harbour in general) for weeks prior to the attack and may have been schooling in the vicinity at the time the attack occurred suggesting a possible case of mistaken identity towards a disturbance on the water surface (West, 2014).

There were no unprovoked shark attacks in Sydney Harbour between 1964 -1995.

Sydney's ocean beaches recorded 40 cases of shark attack from Palm Beach in the north to Botany Bay in the south between 1852 - 2014 (see Table 1). Shark attacks off Sydney beaches became more frequent once the sewage and abattoir by-products started to be discharged from the Malabar ocean outfall from 1916. These attacks were dominated by the White Shark (*Carcharodon carcharias*) involved in 27 cases; Bull Shark (*C. leucas*) has been implicated in 7 cases; unknown Whaler species in 4 cases and the Tiger Shark (*Galeocerdo cuvier*) in 2 cases.

The numbers of fatal shark attacks along the beaches of Sydney in the 1910's to 1930's resulted in the Government of the time installing shark mesh nets off a number of the Sydney beaches from 1937. More beaches were netted from 1949 to 1987 up and down the coast from the Sydney region (Newcastle, Central Coast and Illawarra) (Green, *et al.* 2009).

There were no unprovoked shark attacks recorded at Sydney ocean beaches between 1963 - 2000.

Research on Sydney Harbour Sharks:

Following a serious attack in 2009 by a Bull Shark (*Carcharhinus leucas*) on a Navy diver in Sydney Harbour a research program was initiated by the NSW Fisheries Department to study the Bull Sharks of Sydney Harbour. They captured Bull Sharks

in the harbour, tagged them and tracked the shark's movements using 370 acoustic listening stations around the harbour and along the east coast. It was found that the Bull Shark (*C. leucas*) arrives in Sydney Harbour from November and departs around April each year. However, if water temperatures remained high longer some individuals have been recorded leaving the harbour in May and June (Smoothey, *et al.* in press).

The Bull Shark study found that they swam everywhere in the harbour day and night with one Bull Shark swimming 37km around the harbour in one day. They would occasionally leave the harbour and moved up and down the coast returning to the harbour frequently (Smoothey, *et al.* in press).

The researchers only captured larger sized Bull Sharks (2.2m – 3.12m TL) in Sydney Harbour when the water surface temperature was above 23°C. The water temperature may also be directly, or indirectly, affecting the occurrence in the harbour of large schools of the Bull Shark's prey species including Yellowtail Kingfish (*Seriola lalandi*), Australian Bonito (*Sarda australis*) and Mackerel Tuna (*Euthynnus affinis*). It is suggested that the harbour may be primarily a feeding ground for these sharks and large predatory fish.

The study suggests that Sydney Harbour may also be a site for Bull Sharks to mate as sexually mature Bull Sharks were captured. The known breeding biology for this species indicates they mate in January with 10 -11 month gestation and the young are born in November (Last and Stevens, 2009). The study also noted an absence of neonates suggesting juveniles are not born in Sydney Harbour.

The study did not capture any White Sharks (*Carcharodon carcharias*) or Tiger Sharks (*Galeocerdo cuvier*) in the harbour suggesting that these species are rare occurrences in Sydney Harbour (Smoothey, *et al.* in press; West, 2013).

Comments:

Shark attacks attributed to abattoir operations and discharge of blood and offal directly into the marine environment have been documented in Mogadishu, Somalia (Stevens, 1987) and in Recife, Brazil (Hazin, *et al.* 2008; Hazin and Alfonso, 2014). The presence of an abattoir combined with other impacts from pollution, dumping of rubbish, habitat and environmental changes through estuarine reclamation and the establishment of shipping ports, etc, has been directly implicated in attracting sharks and changing their behaviour resulting in an increase in shark attacks in these areas.

In his paper on shark attacks in Mogadishu Stevens (1987) writes that "the bull shark's diet and known responsiveness to slaughterhouse offal, and the pattern of wounds on victims suggest this species is responsible for the majority of attacks". The paper by Hazin, *et al.* (2008) also indicated that the Bull Shark was involved in the majority of cases in Recife, Brazil.

The Bull Shark (*C. leucas*) is a large free swimming predatory shark with adults growing to around 340 cm total length (TL) but can reach 400 cm TL (McCord and Lamberth, 2009). They can tolerate salinity changes from full strength seawater to freshwater environments and will enter rivers, creeks and lakes and are found along the NSW coast and in Sydney Harbour from November to April. The Bull Shark is a versatile and opportunistic feeder, feeding on a broad range of foods including a

range of fishes, sharks, dolphins, turtles, birds, molluscs, crustaceans and echinoderms. This species starts taking large prey at a relatively small size and it is one of the only sharks that will attack prey larger than itself. Prey items similar in size to humans (e. g. dolphins) start to occur in the diets of Bull Sharks at approximately >200 cm TL (Heithaus, 2001).

In the book 'Shark Attack' by Victor Coppleson (1958) he wrote "The Whaler is believed to be mainly responsible for attacks in bays, harbours, creeks, estuaries and the open sea directly outside harbours" and "it (the Whaler shark) hovers around wharves and meatworks for refuse and offal". The species of Whaler he cites in the book is now known to be the Bull Shark (*C. leucas*).

Although other species of *Carcharhinids* (Whaler sharks) and other potentially dangerous shark species are occasionally observed in Sydney Harbour they have not been implicated in attacks on humans in the harbour, estuarine areas, rivers and creeks as has the Bull Shark (West, 2013).

Discussion:

The three main species of free swimming predatory sharks known to bite people in Australia (White Shark (*C. carcharias*), Bull Shark (*C. leucas*) & Tiger Shark (*G. cuvier*)) all occur in the Sydney region at varying times throughout the year. They all occur along the ocean beaches of Sydney during the summer season and the Bull Shark is known to enter Sydney Harbour between November and April each year when all but two of the shark attacks were recorded in the harbour.

Large free swimming predatory sharks are known to be attracted to sound, smell, taste, vibration, movement, electromagnetic fields and food provisioning. They are also very inquisitive and readily investigate animate and inanimate objects (Strong, 1996; Collier, *et al.* 1996). The discharge of abattoir by-products, sewage and rubbish into the harbour and off the coast over a long period of time (1852 - 1988) may have attracted and possibly altered the behaviour of large predatory sharks.

It could be argued that due to food provisioning from the various pollution sources large free swimming predatory sharks may have become overly stimulated (sensory overload), possibly agitated or even aggressive in the presence of potential food sources. They may more readily react to disturbances in the water, such as people swimming at the water's surface. The disturbance could possibly attract a shark to investigate a potential food item (the source of the disturbance) and bite it, resulting in a case of mistaken identity.

While it may not be possible to distinguish the effect on sharks between abattoir offal, sewage or rubbish in the marine environment, it would be reasonable to assume that blood and offal from an abattoir would attract and possibly excite sharks. It is clear from the records that shark attack incidents dropped dramatically after the closure of the abattoirs in 1988 compared to the period when they were operating and when the human population of the Sydney region was smaller (see Table 1).

The reduction of natural harbour foreshores and pollution from many sources may also have had an adverse impact on the harbour's biologically productive areas

(sources of natural food) and may have altered the sharks foraging behaviour, possibly increasing competition for fewer resources.

The data would suggest that since the progressive improvements in water quality, in the harbour and along the coast and the closure of the abattoir operations in 1988, that the harbour may have returned to a naturally productive ecosystem with abundant food available to predatory fish and sharks. This may have minimised shark interactions with people to the point that shark attack in the Sydney region is a rare event. There were no unprovoked shark attacks in Sydney Harbour between 1964 -1995 and no attacks occurred on any Sydney ocean beach between 1963 - 2000.

Large Bull Sharks are regularly captured in Sydney Harbour (up to 3.12 TL). However, in recent decades the frequency of bites from this species is rare considering the number of people that swim in the harbour throughout the year.

There is also evidence that people and Bull Sharks do coexist in Sydney Harbour. As an example during the Australia Day holiday (26th January 2011) there were 7 tagged Bull Sharks being tracked swimming around the harbour and there were thousands of people swimming in the harbour throughout the day (Daily Telegraph, 2011). These circumstances occur every summer yet there have been no unprovoked shark attack fatalities in the Sydney region since 1963.

However, with the increasing human population in Sydney (~4.5 million in 2014) and the ever increasing participation in recreational water activities, the risk of an interaction with a shark and the possibility of a shark bite would seem inevitable, albeit a very small risk (West, 2011).

Separate to this paper but relevant to this topic the author believes that it is important to note that there are many practical things that people can consider to minimise the risk of encountering a shark and stay safe at the beach. The best prevention is common sense related to where you swim and what activities you undertake whilst in the water. Planning the day at the beach is essential and there are a number of safety points to consider. These can be found on the Taronga Zoo web site in the Australian Shark Attack File information (at <http://taronga.org.au/animals-conservation/conservation-science/australian-shark-attack-file/prevention-shark-attacks>).

Summary of Influences that may have contributed to an increase in shark attacks in the Sydney region.

Sharks attracted to:

Abattoir operations - discharged directly into the harbour,
 Sewage discharged directly into the harbour,
 Discharge from ocean outfall of sewage and offal in close proximity to the shore,
 Discharge of rubbish & offal from barges in close proximity to Sydney beaches,
 Fish congregating around outfalls which sharks feed on,
 Whaling station operations,

Shark may also have been adversely affected by:

Reclamation of harbour habitat - minimising biodiversity, natural food production and availability,
 Toxic pollution in sediment - affecting biodiversity and natural food availability.

Influences that may have contributed to a decrease in shark attacks in the Sydney region.

These include:

Closure of abattoir operations - no discharge of offal into the harbour or ocean outfalls,
 Progressive closure of sewage & toxic waste discharge into the harbour,
 Progressive diversion of sewage discharge to ocean outfalls,
 Extending the ocean outfalls discharge points 3-5 kilometres further off shore,
 Pre-treatment of sewage to ocean outfall discharge,
 Stopping the dumping of rubbish and offal from abattoirs from barges,
 Closure and removal of the whaling station operations in the harbour,
 Development of Surf Life Saving Clubs on Sydney beaches from 1907,
 Installation of a shark meshing program off ocean beaches around the Sydney region from 1937,
 Improvements in the water quality of Sydney Harbour - enhancing natural food production and availability to sharks,
 Banning commercial fishing within Sydney Harbour - improving natural food production and availability to sharks,
 Better understanding of shark behaviour resulting in public awareness programs, risk reduction advice and safety guidelines available to the public.

Acknowledgements: I would very much like to thank the following people for their review of this article and their advice: Gregor Cailliet – Professor Emeritus, Moss Landing Marine Laboratories, Samuel Gruber - Bimini Biological Field Station, University of Miami, John Paxton, Australian Museum, Vic Peddemors - Senior Research Scientist, NSW DPI, and Dennis Reid - Research Scientist, NSW DPI. Also Simon Duffy - Director, Life Sciences, Research & Conservation, Rebecca Spindler – Manager, Research & Conservation and David Skip - Research Biologist, at Taronga Conservation Society Australia.

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