CMS/Sharks/MOS4/Inf.7

HUMAN IMPACTS ON SHARKS AND RAYS

CMS

CMS SHARKS MOU

IUCN SSC
Shark Specialist Group

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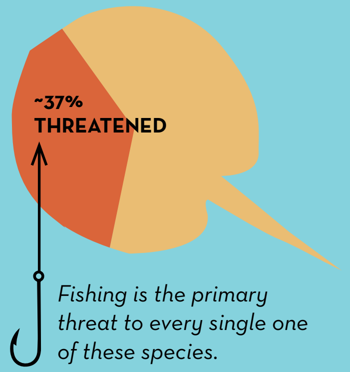
Cover | Aerial of snorkeller on a coral reef, Hawaii
KimberlyJeffries | Ocean Image Bank

Kimbe Bay, Papua New Guinea
Matt Curnock | Ocean Image Bank

THE IMPACTS OF OVERFISHING ON SHARKS AND RAYS

DR. SIMON J. PIERCE

Of the ~1,250 known species of sharks, rays, and ghost sharks (chimaeras), 391 are presently threatened with extinction.



Overfishing has already led to the probable global extinction of three shark and ray species, and several more are now extinct throughout most of their historical range.

OVERFISHING REFERS TO WHEN FISH ARE REMOVED FROM A POPULATION FASTER THAN THEY CAN REPLACE THEMSELVES THROUGH REPRODUCTION.

Of the approximately 1,250 known species of sharks, rays, and ghost sharks (chimaeras), 391 are presently threatened with extinction. Fishing is the primary threat to every single one of those threatened species. Overfishing has already led to the probable global extinction of three shark and ray species, and several more are now extinct through most of their historical range. All the sharks and rays listed on the Convention on the Conservation of Migratory Species of Wild Animals (CMS) are there primarily because their populations drastically declined due to overfishing.

Of course, wild fisheries are also a vital protein source for people. This has been the case for millennia, with evidence of fisheries traced back at least 40,000 years. Contemporary excavations of archaeological sites routinely identify sharks and rays that are no longer present in those countries, particularly distinctive animals like sawfish (family Pristidae), which are now presumed to be extinct in more than half of the 90 nations in which they were historically found. However, even with this long history of exploitation, it is only over the past century that catch rates have dramatically accelerated. The rise of motorized vessels and other fishing technologies has allowed for the use of larger nets and more hooks on longlines, boats to operate further from shore, and opened global markets enabling the routine regional and international trade of fish products.

The contemporary harvest of sharks and rays is estimated at approximately 1.5 million tonnes annually. This is driven largely by the demand for fins and meat for consumption, while other derivatives such as liver oil, gill plates (for Manta and Devil Rays), cartilage, and skin for leather are sometimes sold as well. That said, it is important to keep in mind that a large proportion of shark and ray landings are from incidental catches in fisheries targeting teleost species, such as purse seine and longline fisheries for tuna or gillnets for coastal species. In fisheries science, the term target generally refers to the desired catch. The terminology used for accidentally caught species can vary between fisheries and has been somewhat controversial. However, the terms byproduct and bycatch usually refer to species that are not targeted, are caught accidentally, and are either retained for sale or discarded (dead or alive). There are a number of well documented targeted shark and ray fisheries around the world, but almost all shark and ray species, from 20 m Whale Sharks (*Rhincodon typus*) to 20 cm Dwarf Lanternsharks (*Etmopterus perryi*), many with no commercial value, are accidentally caught.

At a high level, shark, ray, and chimaera (ghost sharks) fisheries can be categorized as recreational, artisanal, or industrial. These labels represent a continuum, rather than a strict demarcation, but provide useful context to the diverse fisheries that catch these species. Recreational fishing, or sport fishing, is broadly defined as catching fish as a leisure activity, either for personal consumption or for the perceived challenge (e.g., where the fish are intended to be released alive). Artisanal fisheries, also referred to as small-scale or subsistence fisheries, are here defined as those involving relatively small vessels (usually less than 20 m in length), fishing in national waters, generally for less than a week at a time. The catch may be for local consumption, export, or both. Industrial, or commercial fisheries, use larger, often more technologically advanced vessels capable of multi-day trips, and aim to sell their catch for a profit.

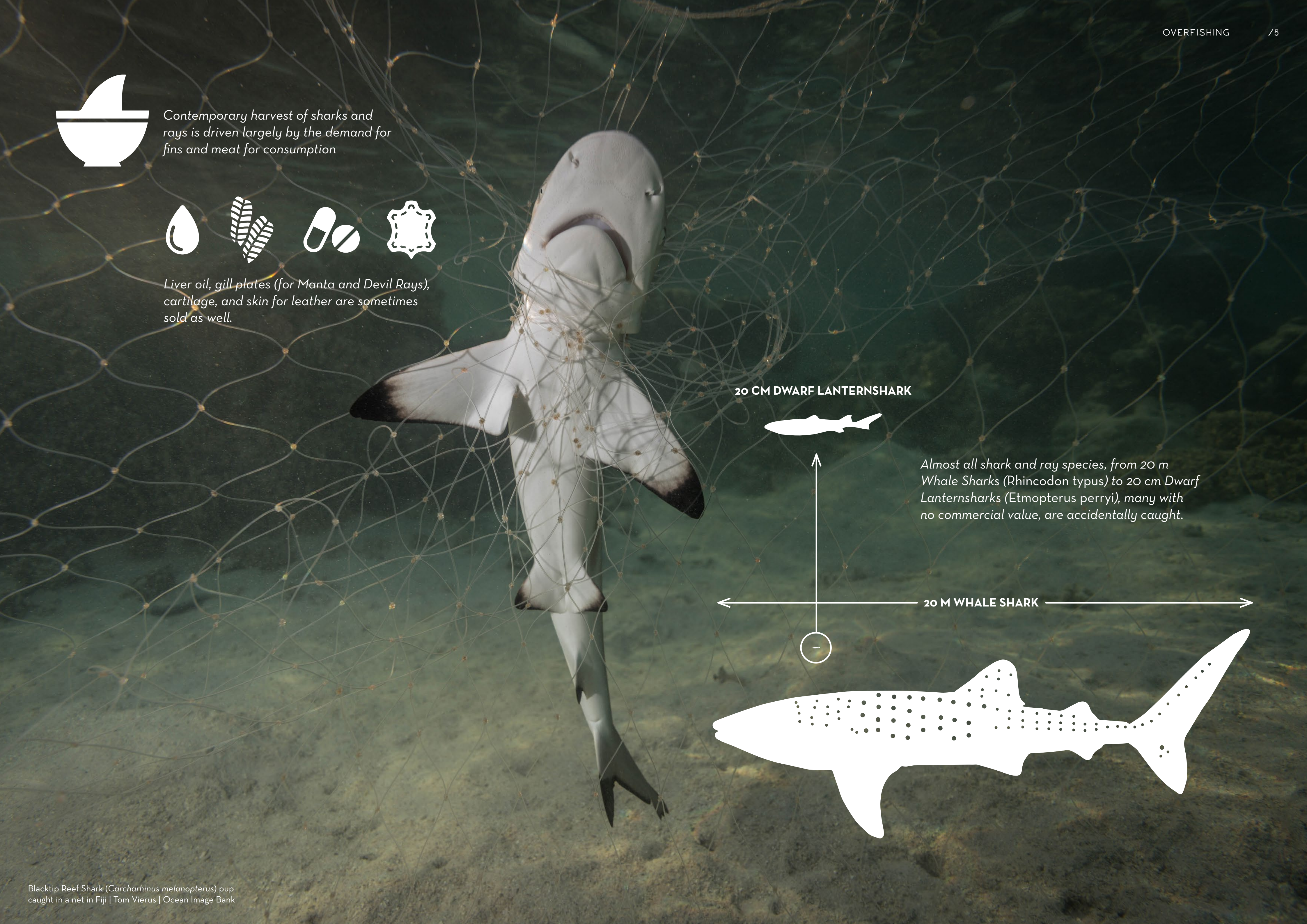
In this fact sheet, we will look at the general characteristics of these fisheries and the threat they pose to sharks and rays, with a particular focus on those listed on CMS and the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), and identify some of the proven approaches we can use to help shark and ray populations recover, without diminishing the contribution of fishing to food security.

Cover | Whipray (*Pateobatis* sp.) caught in an artisanal net fishery in Tanzania | Simon Pierce

The infographics in this factsheet are based off of published literature and are intended as visual representation only.

Contemporary harvest of sharks and rays is driven largely by the demand for fins and meat for consumption

Liver oil, gill plates (for Manta and Devil Rays), cartilage, and skin for leather are sometimes sold as well.



Almost all shark and ray species, from 20 m Whale Sharks (Rhincodon typus) to 20 cm Dwarf Lanternsharks (Etmopterus perryi), many with no commercial value, are accidentally caught.

Blacktip Reef Shark (*Carcharhinus melanopterus*) pup caught in a net in Fiji | Tom Vierus | Ocean Image Bank

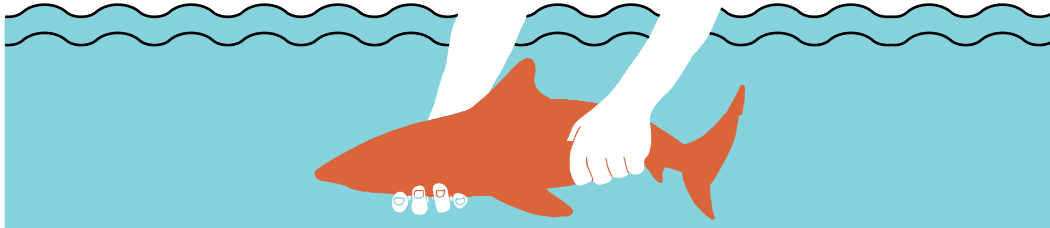
RECREATIONAL FISHERIES

The worldwide recreational catch of sharks and rays is poorly documented. Overall, the reported recreational harvest for all fish is approximately 1% of the total global fish catch. In these fisheries, most sharks and rays – typically 70–100% – are released after capture, rather than retained, so they are not included in this total. The majority of recreational shark and ray fishing takes place on the subtropical and tropical coasts of high-income countries, with the best data available from Australia and the USA, although anglers routinely target sharks and rays in other countries too.

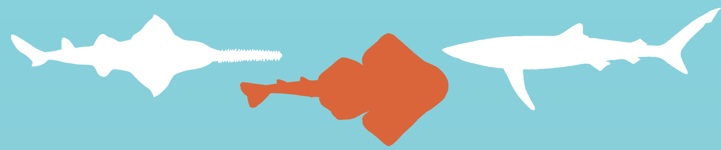
A major national survey of recreational shark and ray fishing in Australia in 2000–2001 found that anglers catch over 1.2 million sharks and rays per year, releasing around 80% alive. More recently, dedicated monitoring efforts in Western Australia (WA) found that 33 shark and ray species were caught, dominated by the Dusky Shark (*Carcharhinus obscurus*). Catch reconstructions found the annual recreational catch to be increasing over time, from 14 tonnes (t) in the early 1940s to 83 t in 2017–2018. An estimated 17,000 individual sharks and rays from all species are caught by recreational anglers in WA each year, with about 82% of them released. Aside from the Dusky Shark, catches of other CMS-listed species were considered negligible (less than 1 tonne in 2017–2018), and the recreational catch was assessed as being unlikely to impact overall shark and ray stocks. In comparison, the industrial catch of sharks and rays in WA is around 1,000 t.

However, there were some catches of species assessed as Critically Endangered on the IUCN Red List of Threatened Species, including sawfishes (family Pristidae), Scalloped Hammerheads (*Sphyrna lewini*), and Oceanic Whitetip Sharks (*Carcharhinus longimanus*), which could warrant management attention, especially since some are highly susceptible to post-release mortality even if released alive.

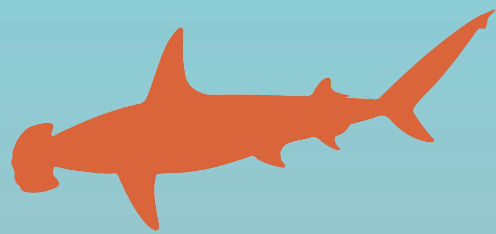
Recreational fishing for sharks is also popular in Florida, USA. The total recreational catch of sharks in Florida was estimated at 733,000 in 1986. A recent study surveyed the 18,000 anglers (as of December 2020) that held permits for recreational shore-based shark fishing. The 856 respondents caught 9,617 sharks over a 12-month period in 2019–2020. Shore-based shark fishing is rapidly growing in participation, increasing around 60% from 2019 to 2020. The most commonly caught CMS-listed species was the Great Hammerhead (Sphyrna mokarran; 309 sharks), but Scalloped Hammerheads, Dusky Sharks, and Shortfin Mako Sharks (*Isurus oxyrinchus*) have also been documented from this fishery. Hammerheads and Dusky Sharks are mandated release species, and release rates overall are thought to exceed 80%.



70-100% of sharks and rays are typically released after capture rather than retained in recreational fisheries.



Pregnant and gravid sharks and rays as diverse as Largetooth Sawfish (Pristis pristis), Angelsharks (Squatina squatina), and Blue Sharks (Prionace glauca), commonly abort their young due to capture stress.



Hammerhead Sharks are known to have a relatively high rate of post-release mortality due to the stress of capture.

Therefore, the possibility of negative population-level effects needs to be considered when there is recreational fishing pressure on key shark and ray habitats, such as inshore nursery areas, or on Critically Endangered species.

The high release rate of sharks and rays in recreational shark fisheries around the world can create opportunities for data collection on poorly known species. For example, Whitespotted Wedgefish (*Rhynchobatus djiddensis*) are targeted by shore anglers along the eastern coast of South Africa, and have primarily been released since 1995. Marker tags were provided to participating anglers, and over 4,700 individual wedgefish were tagged and released between 1984 and 2017. Three hundred and forty recaptures were reported, providing valuable information on the movements of the species, as well as data on population structure and abundance.

Whitespotted Wedgefish are generally a hardy species, with a high survival rate when handled carefully. However, other species are susceptible to capture stress, injury, or post-release mortality, adding pressure on sharks and rays that are already threatened by other processes. Pregnant and gravid sharks and rays as diverse as Largetooth Sawfish (*Pristis pristis*), Angelsharks (*Squatina squatina*), and Blue Sharks (*Prionace glauca*), commonly abort their young due to capture stress. Hammerhead Sharks, in particular, are known to have a relatively high rate of post-release mortality due to the stress of capture. Therefore, the possibility of negative population-level effects needs to be considered when there is recreational fishing pressure on key shark and ray habitats, such as inshore nursery areas, or on Critically Endangered species.

Adult Angelshark (*Squatina squatina*) | Michael Sealey

ARTISANAL FISHERIES

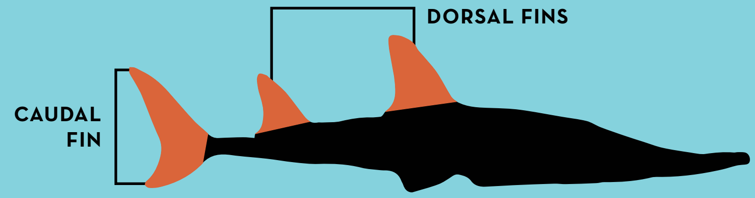
Artisanal fisheries are an important economic sector and a vital contributor to food security in most coastal areas around the world. In many developing countries where fish consumption is important, much of the catch, including shark and ray meat, is consumed domestically. For example, locally-caught fish accounts for 60–70% of the animal protein eaten by people in the Union of Comoros, while the artisanal fleet accounts for over 80% of the national fish catch in Madagascar.

While artisanal fisheries are sometimes called 'small-scale', they can still have a large footprint in coastal areas. Fishing pressure has increased in line with rapid human population growth. For example, the estimated number of non-motorised fishing vessels in Madagascar rose from 2,471 in 1950 to 52,561 in 2016. This trend is replicated all over the world. By 2019, Oman had over 25,000 artisanal boats, Bangladesh about 67,600 vessels, and there are now over 600,000 artisanal fishing vessels in Indonesia. The impact of these fisheries is only increasing with time.

Sharks and rays have always been a common byproduct of these fisheries, but the rapid rise in demand and price for shark and shark-like ray fins has led to increased targeting of some species, and severe population declines as a result. In particular, the shark-like rays (order *Rhinopristiformes*), including sawfishes, guitarfishes, and wedgefishes, are now among the world's most threatened ocean wildlife. Wedgefish species include the CMS-listed Bottlenose Wedgefish (*Rhynchobatus australiae*) and two species on the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), the Whitespotted Wedgefish and Smoothnose Wedgefish (*Rhynchobatus laevis*). Wedgefishes are caught using a variety of fishing techniques, live in shallow coastal waters, and are extremely valuable. Aside from their meat, which is reportedly sold at high prices locally and internationally, the two dorsal and caudal fins of this group have been considered the most expensive 'shark fins' for at least 200 years in China. Large wedgefishes have been sold for up to US$680 each, while prices for their fins can reach as high as US$964 per kg in Asian markets. These high prices have driven fishers to target these species in many regions of the world as well as high levels of retention if caught as bycatch.

Many artisanal fisheries keep their operating costs low by sharing profit from catches, rather than paying fixed salaries for labour. Catching even a small number of high-value sharks or rays can be a major boost to income, incentivizing the continued targeting of these species even as they edge closer to extinction with steep population declines. All except one of the 17 wedgefishes and giant guitarfishes were recently assessed as Critically Endangered. These 16 species are all inferred to have undergone population reductions of more than 80% over the last 30–45 years. The intensity of fishing pressure on coastal and shelf waters leaves little refuge for this unique group.

Wedgefishes are caught using a variety of fishing techniques, live in shallow coastal waters, and are extremely valuable.



Aside from their meat, which is reportedly sold at high prices locally and internationally, the two dorsal and caudal fins of this group have been considered the most expensive 'shark fins' for at least 200 years in China.

Large wedgefishes have been sold for up to US$ 680 each

Prices for wedgefishes fins can reach as high as US$ 964 per kg in Asian markets

These high prices have driven fishers to target these species in many regions of the world as well as high levels of retention if caught as bycatch.

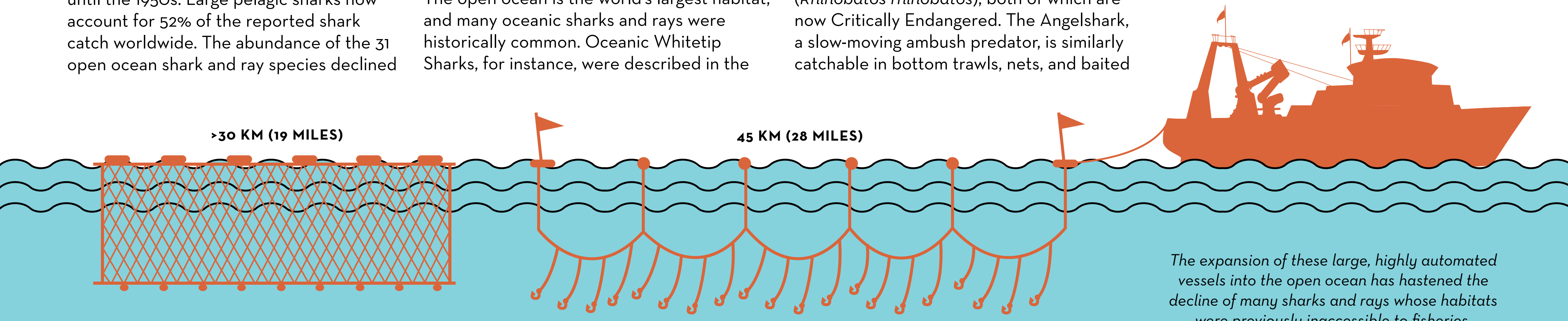
INDUSTRIAL FISHERIES

Industrial fisheries are another immediate global threat to many sharks and rays. Modern industrial fishing vessels tend to be large, can operate around the clock, and are often capable of extended trips (in both time and distance) into international waters, with many ships having onboard processing and freezing facilities. Depending on target species, some vessels have the capacity to deploy huge nets, often exceeding 30 km (19 miles) in length, while an average longline set in US waters is 45 km (28 miles). The expansion of these large, highly automated vessels into the open ocean has hastened the decline of many sharks and rays whose habitats were previously inaccessible to fisheries.

Most industrial fishing did not start regularly targeting sharks in international waters until the 1950s. Large pelagic sharks now account for 52% of the reported shark catch worldwide. The abundance of the 31 open ocean shark and ray species declined by 71% from 1970 to 2018 due to an 18-fold increase in relative fishing pressure over that period. While oceans cover huge areas, sharks and rays are not evenly distributed; major oceanographic features, such as the Gulf Stream in the North Atlantic and the East Australian Current in the southern Pacific Ocean, aggregate multiple pelagic shark species together. The industrial fleet is well aware of this, and fishing effort is concentrated on these productive areas. A recent major tracking study, aggregating 1,804 satellite tracks from 23 pelagic shark species, compared shark occurrence hotspots to the position of industrial fishing vessels. Sharks and shark fishers showed a high degree of overlap, up to 76% for Blue Sharks in the North Atlantic. Distance from shore is no longer a refuge for these species.

The open ocean is the world's largest habitat, and many oceanic sharks and rays were historically common. Oceanic Whitetip Sharks, for instance, were described in the 1964 'Natural History of Sharks' as being "extraordinarily abundant, perhaps the most abundant large animal... on the face of the earth". Twenty-four of these 31 species are now threatened with extinction. The formerly abundant Oceanic Whitetip has suffered a >98% reduction in numbers; they are now Critically Endangered.

Industrial fisheries that accidentally catch slow-growing sharks and rays can remain profitable even while species decline to local or global extinction. The Angelshark is a good example of this scenario. As fishing effort and capabilities increased during the 20th century, there was a well-documented decline of large bottom-dwelling sharks and rays in European waters, including the ironically named Common Blue Skate (*Dipturus batis*) and Common Guitarfish (*Rhinobatos rhinobatos*), both of which are now Critically Endangered. The Angelshark, a slow-moving ambush predator, is similarly catchable in bottom trawls, nets, and baited lines, which operate through most of its coastal habitat in Europe and northwestern Africa. Initially, Angelsharks were caught in targeted fisheries, but as their numbers plummeted these fisheries were no longer viable. However, the numbers of faster-breeding teleost species that shared their coastal habitat, such as Anglerfish (*Lophius* spp.), remained high, so these fisheries could catch and market these fish to operate profitably despite the declining shark catches. The Angelshark is also now Critically Endangered, extinct through most of its historical range, with no recorded industrial landings of the species in the North Sea since the 1970s. The species remains relatively common only in the Canary Islands, where trawl fishing has been prohibited since 1986.



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Modern industrial fishing vessels tend to be large, can operate around the clock, and are often capable of extended trips (in both time and distance) into international waters, with many ships having on-board processing and freezing facilities. Depending on target species, some vessels have the capacity to deploy huge nets, often exceeding 30 km (19 miles) in length, while an average longline set in US waters is 45 km (28 miles).

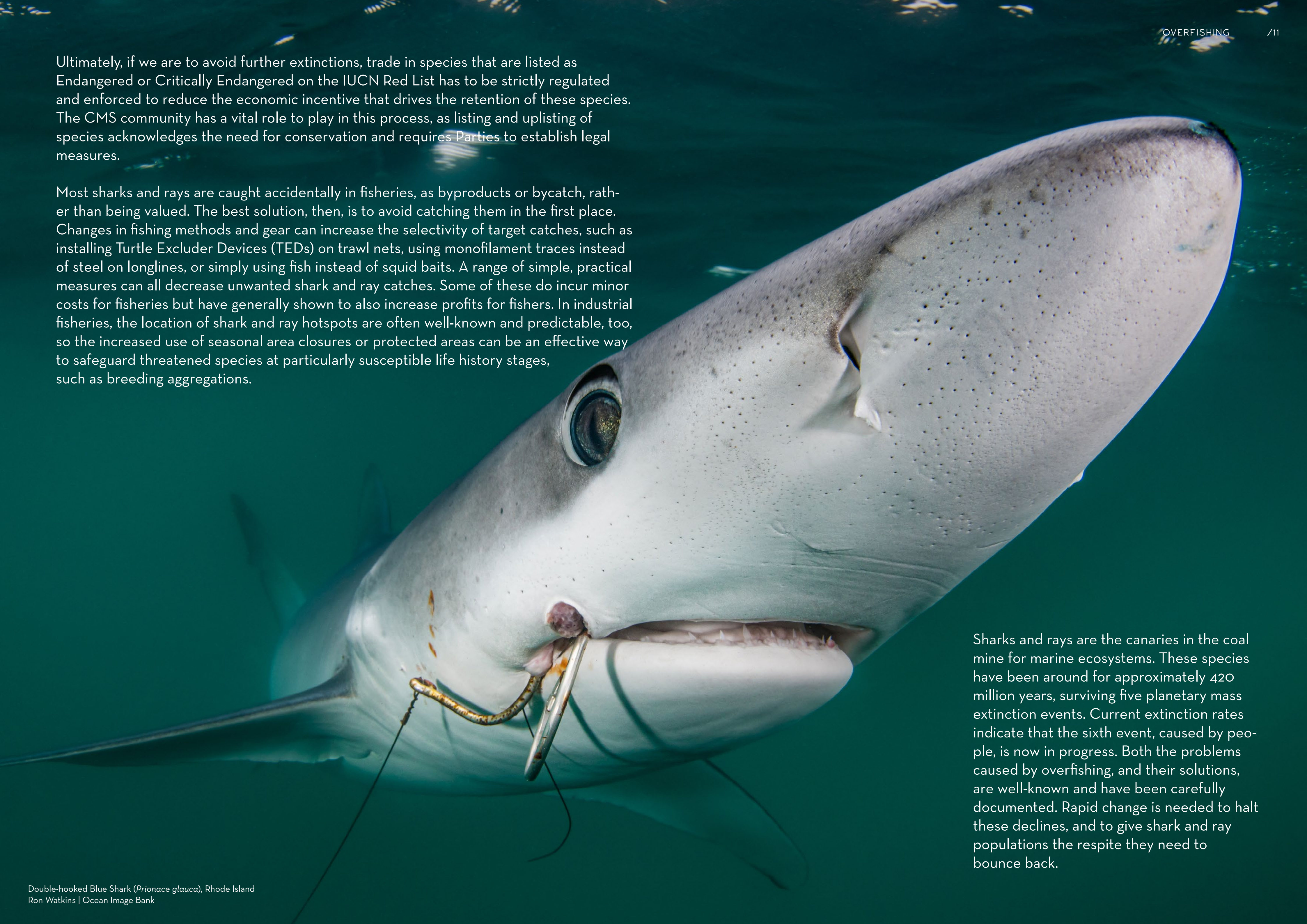
LOOKING FORWARD

In many countries, shark and ray landings make an important contribution to food security. For millions of people living in developing countries, fish are not an optional complement to a rich variety of foodstuffs, but a critical protein source. Fishes contain micronutrients that help to prevent nutrient-deficiency diseases, a leading cause of infant mortality worldwide. However, targeted fisheries for sharks and rays are the exception, not the rule. Most sharks are accidentally caught in fisheries targeting fast-growing teleost or invertebrate species. Even pelagic sharks and rays, which make up the bulk of the international trade in shark products, are typically caught in fisheries targeting more valuable tuna and billfish species. These fishes are two to three-fold more productive than sharks and rays, so they are often more resilient to overfishing and can rebound faster in response to management initiatives. In contrast, the slow breeding rate of most sharks and rays means that recovery times from even modest overfishing can take decades.

Sustainable shark and ray fisheries are demonstrably possible. The small Common Thresher Shark (*Alopias vulpinus*) fishery in the northeast Pacific, and Spiny Dogfish (*Squalus acanthias*) in the northwest Atlantic, are two widely accepted examples amongst CMS-listed species. However, the high bar that such a designation requires – regular, published stock assessments and a science-based management plan – have seldom been met outside industrial fisheries, in high-income countries, overseen by well-resourced fisheries management agencies. Even wealthy countries, though, generally view the reduction of threatened species bycatch as a secondary consideration to maintaining catches of valuable target species. Perversely, only 46% of open ocean fisheries would even be profitable without major government subsidies to industrial fishing companies. In addition, many artisanal fisheries are largely unmanaged, and few data are available on catches. Striving to make all shark fisheries sustainable is a laudable goal, but it is unlikely to happen fast enough to prevent the rapid decline of many sharks and rays to ecological and global extinction.

International trade in shark and ray products is a primary driver of overexploitation. Much of this trade has historically been for luxury goods, such as shark fin soup, that play no meaningful role in food security. Many CMS-listed sharks and rays are also listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which generally prohibits (Appendix I) or regulates (Appendix II) international trade of listed sharks and rays. The species listed in Appendix II can be legally traded if the exporting country can demonstrate that products are derived from a population that is managed for sustainability. However, less than 5% of shark and ray species are currently listed on international treaties, and a significant amount of international trade in listed species still evades this process by exploiting illegal channels and mislabelling.

Oceanic White Tip Shark (*Carcharhinus longimanus*)
Fabrice Dudenhofer | Ocean Image Bank



Ultimately, if we are to avoid further extinctions, trade in species that are listed as Endangered or Critically Endangered on the IUCN Red List has to be strictly regulated and enforced to reduce the economic incentive that drives the retention of these species. The CMS community has a vital role to play in this process, as listing and uplisting of species acknowledges the need for conservation and requires Parties to establish legal measures.

Most sharks and rays are caught accidentally in fisheries, as byproducts or bycatch, rather than being valued. The best solution, then, is to avoid catching them in the first place. Changes in fishing methods and gear can increase the selectivity of target catches, such as installing Turtle Excluder Devices (TEDs) on trawl nets, using monofilament traces instead of steel on longlines, or simply using fish instead of squid baits. A range of simple, practical measures can all decrease unwanted shark and ray catches. Some of these do incur minor costs for fisheries but have generally shown to also increase profits for fishers. In industrial fisheries, the location of shark and ray hotspots are often well-known and predictable, too, so the increased use of seasonal area closures or protected areas can be an effective way to safeguard threatened species at particularly susceptible life history stages, such as breeding aggregations.

Sharks and rays are the canaries in the coal mine for marine ecosystems. These species have been around for approximately 420 million years, surviving five planetary mass extinction events. Current extinction rates indicate that the sixth event, caused by people, is now in progress. Both the problems caused by overfishing, and their solutions, are well-known and have been carefully documented. Rapid change is needed to halt these declines, and to give shark and ray populations the respite they need to bounce back.

Double-hooked Blue Shark (*Prionace glauca*), Rhode Island
Ron Watkins | Ocean Image Bank

FURTHER READING

Shark recreational fisheries: Status, challenges, and research needs. Gallagher AJ, Hammerschlag N, Danylchuk AJ, Cooke SJ (2017) Ambio 46(4): 385–98.

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Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH, Herman KB (2021) Current Biology 31(21): 4773–87.

Hammerhead Shark in fishing net, Hawaii
Toby Matthews | Ocean Image Bank

THE IMPACTS OF HABITAT DEGRADATION AND LOSS ON SHARKS AND RAYS

DR. SIMON J. PIERCE

HABITAT DEGRADATION AND LOSS: 'THE ELIMINATION OR ALTERATION OF THE CONDITIONS NECESSARY FOR ANIMALS AND PLANTS TO SURVIVE.'

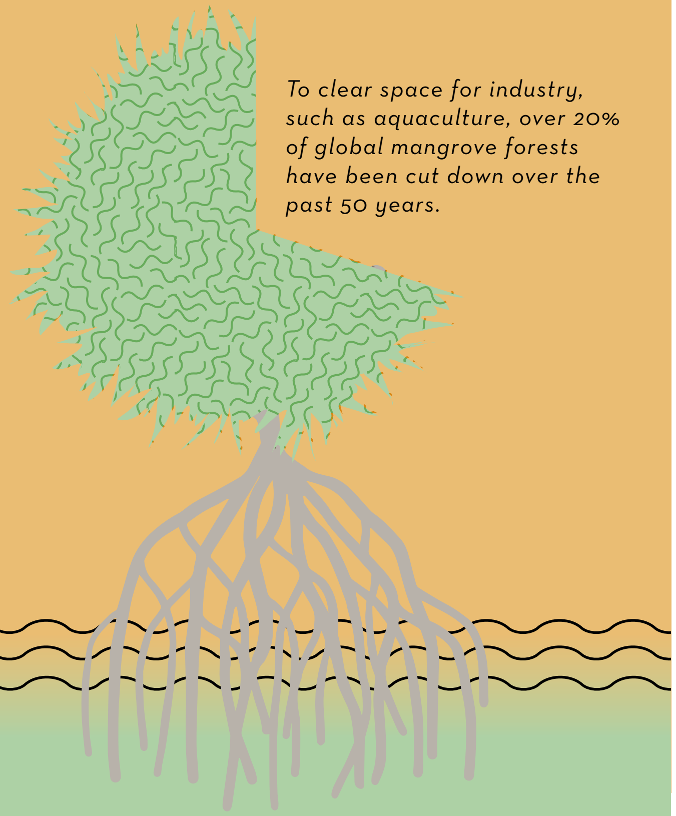
Sharks, rays, and their relatives live throughout the world's marine and freshwater systems, from the Arctic Ocean to the Zambezi River in Africa. Most are virtually unknown to us, with some living down to 3,000 m (1.86 miles) beneath the surface – many of the 1,250+ species have never even been seen alive in their natural habitats. Others, though, are much more familiar. People have been using coastal seas and freshwater areas for millennia and have a long history of interactions with the sharks and rays that also depend on these habitats to provide sheltered nursery grounds, feeding areas, and reproductive sites.

Habitat degradation and loss can occur through many human-driven processes such as mangrove deforestation, dam construction, or nets uprooting coral and seagrass communities. These damaged ecosystems become less resilient to change, and their reduced productivity means they can support fewer species and a lower abundance of life. As our populations continue to increase over the next century, and industry activities steadily move into deeper waters, it is vital that we understand how human-induced changes have, and will, affect sharks and rays.

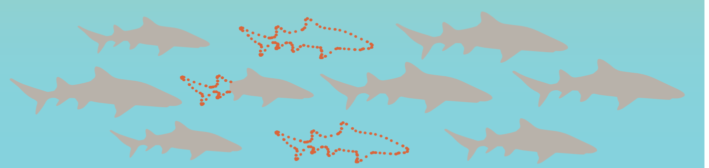
This fact sheet provides an overview of how habitat modification can disrupt the lives of sharks and their relatives, particularly those listed on the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), and how we can get better at sharing space with these amazing fishes.

Cover | A mangrove and seagrass-lined bay in Raja Ampat, Indonesia | The Ocean Agency | Ocean Image Bank

Eagle Rays in seagrass (*Thalassia testudinum*), Quintana Roo, Mexico | Ben Jones | Ocean Image Bank



To clear space for industry, such as aquaculture, over 20% of global mangrove forests have been cut down over the past 50 years.



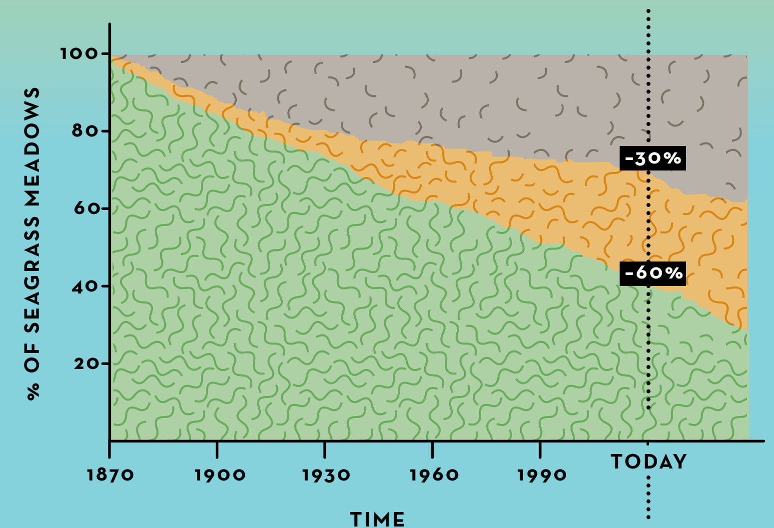
Construction of a large resort complex in the 1990s, involving substantial dredging and mangrove clearance, led to a 23% decline in the first-year survival of Lemon Shark pups.

MANGROVE FORESTS AND SEAGRASS MEADOWS

Many ocean-dwelling sharks and rays rely on shallow bays and estuaries as nurseries for their pups. These are among the most productive environments on the planet, providing a seafood buffet for these trainee predators. Critically, mangroves and shallow bays also provide the small pups with a refuge from larger hunters. These coastal areas are also great places for people to live and work. To clear space for industry, such as aquaculture, agriculture, plantations, and coastal development, as well as exploitation for timber and fuel wood, an estimated 20% (3.6 million hectares) of global mangrove forests have been cut down between 1980 and 2005. Siltation from degraded rivers and dredging chokes shallow seagrass beds, leading to an almost 30% global loss of seagrass meadows from the 1870s to the present.

These human impacts can tip the delicate balance that young sharks face: to find food, while not becoming food themselves. Lemon Sharks (*Negaprion brevirostris*) in the Bimini Islands, Bahamas, are probably the world's best-studied shark population. Construction of a large resort complex in the 1990s, involving substantial dredging and mangrove clearance, led to a 23% decline in the first-year survival of Lemon Shark pups. The loss of mangroves reduced the escape routes for these small sharks, while the siltation of seagrass beds simultaneously meant there were fewer fish for them to hunt.

Built structures can also affect sharks and rays, both directly and indirectly. The southeast Florida coast in the USA is a nursery area for young Giant Manta Rays (*Mobula* cf. *birostris*). The number of people living in Florida has increased rapidly, 262% from 1960 to 2008, with three quarter of residents living along the coast. To accommodate leisure and commercial access to the ocean, the construction of piers and marinas has increased boat traffic and fishing pressure. Recent surveys found that 46% of these small Manta Rays bear wounds, most from propeller strikes and fishing gear entanglement. Manta Rays typically have just a single pup every 4-5 years, so reduced survival of these baby rays can quickly lead to a population crash.



Siltation from degraded rivers and dredging chokes shallow seagrass beds, leading to an almost 30% worldwide loss of seagrass meadows from the 1870s to the present.

RIVERS AND LAKES

About 5% of all shark and ray species live in, or regularly enter tropical rivers and lakes. Many of these are rays, including the Largetooth Sawfish (*Pristis pristis*) and the beautifully patterned South American freshwater stingrays (family Potamotrygonidae). Some sharks also use rivers, particularly River Sharks (*Glyphis* spp.) and Bull Sharks (*Carcharhinus leucas*), who often spend the first few years of life in freshwater.

Freshwater provides us with a critical resource for drinking, bathing, transport, agriculture, fisheries, and energy generation. While some freshwater systems are enormous, such as the Amazon and the Ganges rivers, human pressures can still have an outsized impact on the fish that live there. Flow controls have been imposed on many large rivers to provide safe and predictable access for people; this affects freshwater rays and sharks, who rely on seasonal rainfall and the natural flooding cycle to move within and between rivers.

As an example, the Fitzroy River in northwestern Australia is an important nursery area for Largetooth Sawfish. Adults give birth near the river mouth, and the young pups then swim 300–400 km up the river during floods, finding a safe home in the isolated pools that form in the upper river during the dry season. In an unfortunate comparative study, dam construction in the nearby Ord River has led to the ecological extinction of this Critically Endangered species. Reduced access to suitable riverine nursery areas is a key limiting factor for the five species of sawfishes (family Pristidae), which are now believed to be extinct in 55 countries where they were historically found.

Similarly, the Ganges Shark (*Glyphis gangeticus*) lives in the large rivers that meander down from Asia to the Indian Ocean. The Ganges river basin, which the species is named for, is home to more than 400 million people. The dense human population creates chronic threats, such as fishing pressure and pollution, which – along with the large dams in the river – have led to the extinction of the Ganges Shark in its namesake habitat. In other large rivers that once provided suitable habitat, such as the Indus River in Pakistan, there are four large dams and 22 barrages, with more proposed. The adult population of the Ganges Shark is now estimated to be in the low hundreds, scattered across a historical distribution that extends from Borneo to the Arabian Sea, with habitat loss isolating them from one another and making it harder to find a mate.

Pallam village surrounded by mangroves in East Godavari district | Srikanth Mannepuri | Ocean Image Bank

Freshwater Stingray in the Peruvian Amazon region | Anton Sorokin

SEABEDS AND CORAL REEFS

The relative accessibility of freshwater and coastal marine environments, and the obvious human impact on these habitats, means these areas have been a natural focus of shark and ray research. Other impacts can be tougher for us to see during day-to-day life, but research is helping to make their importance clear.

A good example is bottom trawl fishing which is, by far, the largest source of physical disturbance to the marine environment. Aside from actually catching sharks, rays, and ghost sharks (chimaeras), these weighted nets can literally flatten whole ecosystems when dragged across reefs, deep-sea corals, or sponge beds. Many sharks, such as Catsharks (*Apristurus* spp.), have sticky eggs that they attach to deep-water corals and sponges while the embryo can develop safely inside. The devastation of these habitats, which can take decades or more to recover, even if not disturbed again, multiplies the population loss of susceptible shark and ray species. Demersal species, such as Angelsharks (*Squatina squatina*), can be particularly affected by the impacts of bottom trawling on their habitat and prey, with this Critically Endangered species now locally common only in the Canary Islands, where trawl fishing has been banned since 1986. Habitat loss and degradation compound the overfishing risk for 73 threatened shark and ray species.

Tropical coral reefs and reef flats have also been hard-hit by both direct and indirect human impacts. Many species rely on these productive ecosystems, including reef specialists like the Walking Sharks. Some of these little sharks, such as the Leopard Epaulette Shark (*Hemiscyllium michaeli*) from Papua New Guinea, are restricted to a relatively small part of this biodiverse coast. Degradation of their reef flat habitat by road construction, and land conversion for palm oil – both of which increase sedimentation, smothering their shallow reef habitat – have affected about 20% of the species' range over just the past 10 years. In Tanzania, which has severely depleted reef shark populations, passive acoustic monitoring of dynamite fishing on coral reefs has detected over 1,000 blasts per month until official enforcement targeted this illegal method in 2017–2018. Climate change, and associated coral bleaching events, are creating chronic stress on reef ecosystems. There was progressive loss amounting to 14% of the coral from the world's coral reefs between 2009–2018, which is more than all the coral currently living on Australia's coral reefs. Human pressures on coral reefs across the world are reducing both the quantity and quality of habitat available. Even for widespread reef shark species, this can lead to the decline and fragmentation of their populations.

Blacktip Reef Sharks (*Carcharhinus melanopterus*) on coral reef flat in French Polynesia
Hannes Klostermann | Ocean Image Bank

LOOKING FORWARD

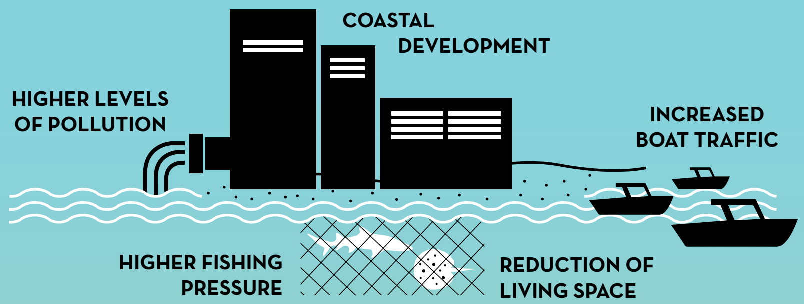
Habitat degradation and loss can, in a frighteningly short amount of time, permanently reduce the available space that sharks and their relatives have to live in. That is particularly tough to deal with for habitat specialists, such as freshwater rays and sharks, and those that have a naturally small distribution. Dietary specialists, such as the Bonnethead Shark (*Sphyrna tiburo*), which has recently been identified as the first omnivorous shark – seagrass makes up an estimated 62% of its juvenile diet, by gut content mass, and up to 40% in adult sharks – may also be at elevated risk.

The species whose range overlaps with dense human populations are disproportionately likely to be threatened. Some are now Critically Endangered, facing a high risk of global extinction. Individual records of Angelsharks in the Mediterranean Sea, sawfishes outside Australia and the USA, or any Ganges Shark occurrence, for example, are often now noteworthy enough for scientists to publish them – a recognized identifier of ecological extinction. For these species, they will clearly be helped by specific measures such as safeguarding natural river flows, fulfilling the CMS mandate to prevent obstacles to the migration of listed species.

Habitat loss is highly correlated with other human pressures. Coastal development is associated with higher levels of pollution, more fishing pressure, and increased boat traffic. Floodplain conversion to agricultural land generally leads to increased siltation, along with pesticide and fertilizer runoff, which in turn affects coral reefs, that are themselves simultaneously impacted by overfishing and climate change. Rather than trying to separate out and address all these issues separately, a recent initiative by the IUCN SSC Shark Specialist Group seeks to identify the world's most 'Important Shark and Ray Areas - ISRAs'. Management and conservation efforts can then focus on the specific areas that are most important to the life cycle of sharks and their relatives, including the most threatened species and those listed on CMS, to maximize the positive impact of protection and restoration.

For all the ocean wildlife that use human-modified areas during part of their lifecycle, which includes most of the world's sharks and rays, preserving and restoring their habitats will speed their recovery from overfishing, and improve their resilience to other challenges. Everyone benefits from healthy oceans, and that means we need to provide space for other animals to thrive alongside people.

Habitat degradation and loss can permanently reduce the available space that sharks and their relatives have to live in. That is particularly tough to deal with for habitat specialists, such as freshwater rays and sharks, and those that have a naturally small distribution.



Habitat loss is highly correlated with other human pressures. Coastal development is associated with higher levels of pollution, more fishing pressure, and increased boat traffic.

FURTHER READING

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THE IMPACTS OF POLLUTION ON SHARKS AND RAYS

DR. SIMON J. PIERCE

POLLUTION IS THE INTRODUCTION OF ARTIFICIAL OR NATURAL CONTAMINANTS OR ENERGIES (SUCH AS LIGHT OR NOISE) INTO THE ENVIRONMENT THAT CAUSE ADVERSE CHANGE.

Until the 1970s, people routinely dumped toxic chemicals and other waste products into the ocean with little understanding of the consequences. We assumed that the vast ocean had an almost unlimited capacity to dilute and disperse our rubbish – out of sight, out of mind. Unfortunately, our steady creation of novel chemicals and long-lasting products, such as plastics, is creating a larger and larger problem for generations to come.

Persistent organic pollutants, heavy metals, crude oil, and marine debris (such as plastic waste, and lost or discarded fishing gear) are the most common ocean pollutants. Some of these substances are used for disease and pest control, or in manufacturing and industrial processes. Others are accidental by-products of waste incineration, vehicle emissions, or forest fires. Pollutants can enter the marine environment from a variety of sources, such as discharge and runoff from agricultural and urban areas, from fishing or transport vessels, and even from winds depositing atmospheric waste onto the ocean surface.

Sharks and rays, many of which are top predators in marine and freshwater ecosystems, are highly susceptible to environmental pollution. Pollutants typically bioaccumulate, where the amount in the animal's body grows faster than their ability to excrete it. This is compounded by biomagnification, where sharks and rays unavoidably ingest the pollutants within their prey species too. When people, in turn, rely on sharks and rays as a source of protein, the pollutants can be passed on to them and their families.

In this fact sheet, we identify the main sources of ocean pollution and how these are likely to impact sharks and rays, with a particular focus on those listed on the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), and explore some of the downstream health implications for people.

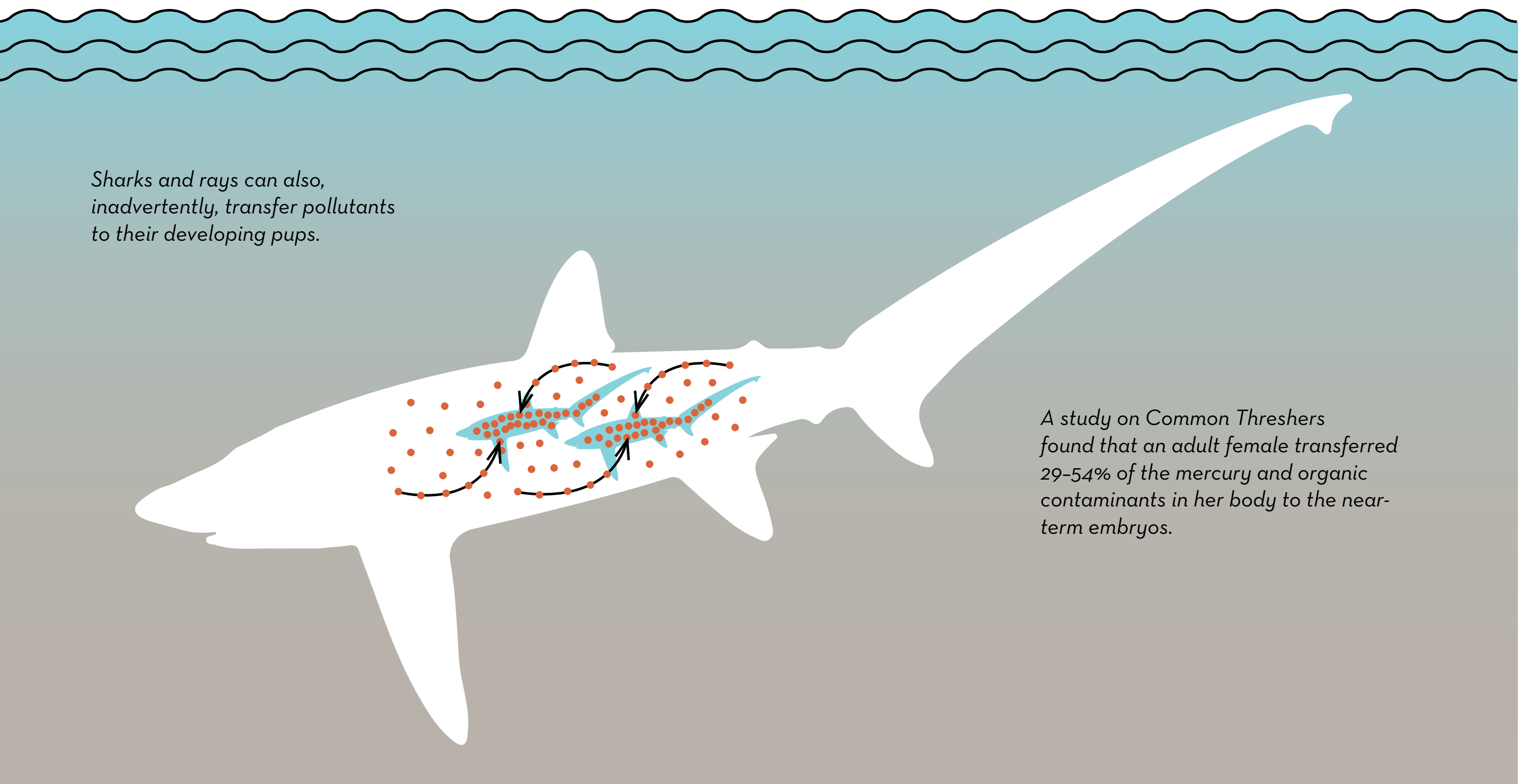
Cover | Reef Manta Ray (*Mobula alfredi*) feeding among plastic pollution at Nusa Penida, Indonesia | Brooke Pyke

Abandoned fishing gear in seagrass, Greece
Dimitris Poursanidis | Ocean Image Bank

TOXIC CHEMICALS AND HEAVY METALS

High concentrations of toxic pollutants, including organic (e.g., PCBs, DDTs, and organochlorines) and inorganic substances (e.g., heavy metals, including mercury), are now routinely found in sharks and rays. Research on the impact of these pollutants on these species is still at an early stage, but studies on marine mammals and teleost fishes have found neurological disorders, structural damage to organs and gills, reduced fertility, developmental effects, and cancers, at levels of pollutant exposure similar to those reported from Blue Sharks (*Prionace glauca*), White Sharks (*Carcharodon carcharias*), Shortfin Makos (*Isurus oxyrinchus*), Common Threshers (*Alopias vulpinus*), and Whale Sharks (*Rhincodon typus*). While shark physiology does not necessarily respond in the same way to other animals, these results are a cause for concern as increasing pollutant loads are documented around the world. Sharks and rays can also, inadvertently, transfer pollutants to their developing pups. A study on Common Threshers found that an adult female transferred 29–54% of the mercury and organic contaminants in her body to the near-term embryos. Similarly, high organochlorine levels have been found in young White Shark pups, presumed to be transferred from their mother's tissue. The elevated levels of pollutants in these young sharks point to a heightened future risk of ill effects, as they will continue to bioaccumulate these contaminants throughout their life-time. While studies of pollutant effects on reproduction have so far focused on sharks that give birth to free-swimming pups, such as those listed above, the permeable eggs of other species, such as the Smallspotted Catshark (*Scyliorhinus canicula*) and skates (family Rajidae) may mean that their embryos cannot avoid exposure to waterborne pollutants during development.

Red tide events, a toxic bloom of *Karenia* spp. dinoflagellates associated with nutrient run-off from agriculture, are increasing in frequency along the southern coast of the United States. In 2000, a large bloom led to the mass death of hundreds of Blacktip (*Carcharhinus limbatus*) and Atlantic Sharpnose (*Rhizoprionodon terraenovae*) sharks in northwest Florida. Examination of the dead sharks found that they also transferred brevotoxins from the algal bloom to their embryos, showing that such maternal transfer can take place for a wide variety of pollutants. Red tides are an ongoing problem for a number of shark and ray species in this region, with a probable Whale Shark death also reported from Florida in 2018.



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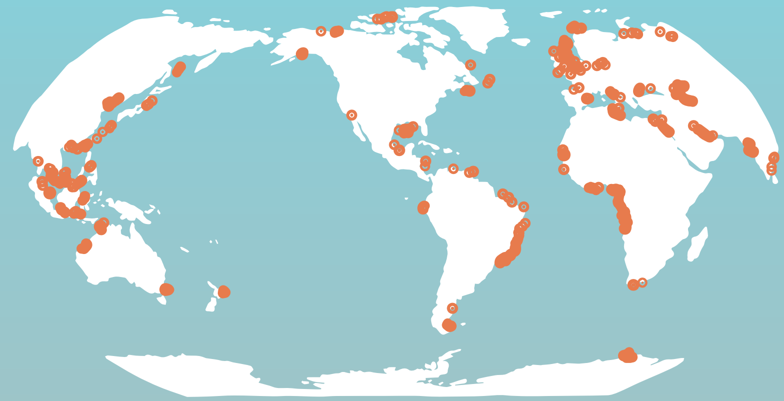
OIL SPILLS

Oil and gas extraction is a huge and growing industry worldwide, including in the ocean. The first offshore oil drilling platform went live in 1947 and, since then, over 12,000 platforms have been constructed on the continental shelves of 53 countries. As engineering improves, platforms are being built in deeper and deeper waters. The potential threat to sharks and rays comes primarily from large-scale oil spills, either from platform blowouts or tanker accidents. However, these activities also increase vessel traffic, which poses an additional collision risk to large surface-feeders like Giant Manta Rays (*Mobula* cf. *birostris*) and Whale Sharks.

The Deepwater Horizon oil spill in 2010 was the largest accidental spill in history and the best-studied incident when considering potential effects on sharks and their relatives. The platform was located in the northern Gulf of Mexico, 66 km off the coast of the United States, with the blowout occurring at 1,500 m depth. An estimated 750 million litres of oil were spilled, covering over 180,000 km² of surface waters, affecting over 2,100 km of coastal habitats, and contaminating surrounding deepwater areas.

Around 80 species of sharks and rays live in the Gulf of Mexico. Their distributions, habitat preferences, biology and ecology, conservation status, and likely exposure to spilled oil, have been modelled to create vulnerability indices to regional oil spills. Sharks and rays had higher overall vulnerability scores than teleost fishes, with the Whale Shark, Giant Manta Ray, and the Scalloped Hammerhead (*Sphyrna lewini*) the most susceptible overall. The Gulf of Mexico is a globally important feeding area for Whale Sharks and Giant Manta Rays, both of which filter-feed on the surface, leading to concerns that both oil spills and the chemical dispersants used as a treatment for spills could damage their respective gill structures. Neonate and small juvenile Scalloped Hammerheads, on the other hand, use coastal nursery areas that could be affected by spills. All three species are globally Endangered or Critically Endangered on the IUCN Red List of Threatened Species.

Some deepwater sharks (occurring at depths of over 200 m) and ghost sharks (chimaeras) have also been identified as highly susceptible to regional oil spills, particularly the Blotched Catshark (*Scyliorhinus meadi*), Caribbean Roughshark (*Oxynotus caribbaeus*), and Smallfin Catshark (*Apristurus parvipinnis*). Between 0.5–25% of the Deepwater Horizon oil spill is estimated to have been deposited on the seafloor, where a sudden influx of organic hydrocarbon can overwhelm natural microbial biodegradation. Field studies have detected polycyclic aromatic hydrocarbons (PAHs), indicative of oil exposure, in deepwater sharks within 100 km of the spill site. Detrimental effects may be particularly high for the species whose egg cases develop over prolonged periods on the seafloor, such as catsharks (family Scyliorhinidae). Eight years after the spill, surveys indicated oil concentrations in coastal areas of Louisiana remained an order of magnitude higher than baseline. With the oil now sequestered in anoxic sediments, levels are expected to remain significantly above background for decades, with ongoing impacts on sharks, rays, chimaeras, and their prey species in the region.



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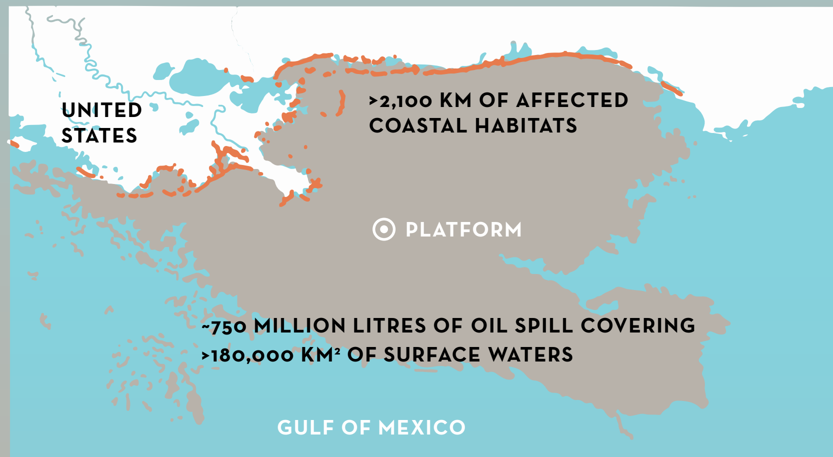

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~80 species of sharks and rays live in the Gulf of Mexico.

Entangled Whale Shark (*Rhincodon typus*) in the Galapagos | Jenny Waack

OCEAN PLASTIC

Rubbish in rivers, beaches, and the open sea is a glaringly obvious problem for anyone that uses these environments. The majority of this rubbish consists of plastic debris. Plastic is cheap to make, lightweight, and durable. Unfortunately, this has led to mass production of disposable packaging which, coupled with poor waste management, adds an estimated 14 million tons of discarded plastic to the ocean each year. Based on current trends, the quantity of plastic trash entering the ocean is expected to triple by 2040.

These plastics are widely distributed by winds and currents, traveling out to sea, washing up on distant beaches, settling into deep-sea trenches, and almost everywhere in between. This waste is projected to take hundreds of years to degrade. The major threat to sharks from plastic comes from entanglement, particularly in discarded fishing gear ('ghost nets'), along with internal injuries and pollutant offloading from ingested plastic.

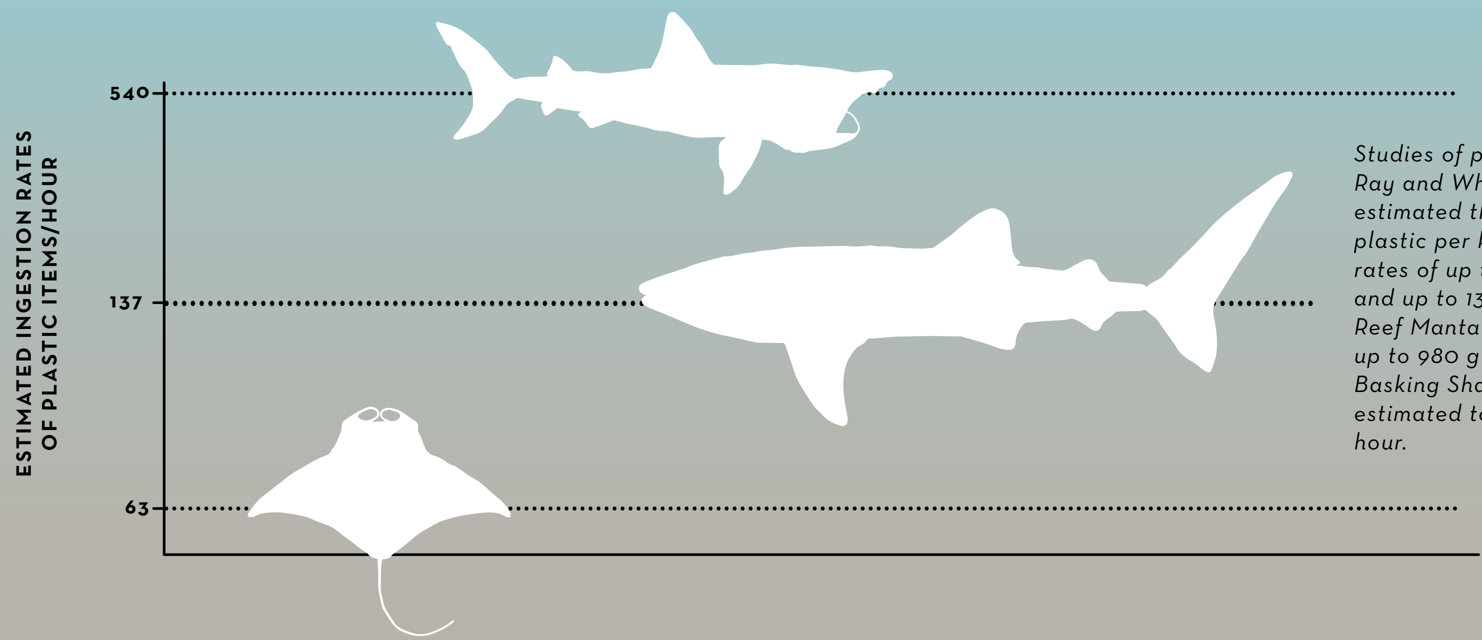
Around 6.4 million tonnes of fishing gear is lost in the world's oceans each year. Ghost fishing gear commonly consists of synthetic nylon nets that can passively drift in currents over large distances. These nets are, by design, hard for ocean wildlife to detect, and they can trap and kill animals for many years. Migratory sharks and rays, some of which swim thousands of kilometres each year to feed and breed, are one of the worst affected groups. Oceanic species, such as Silky Sharks (*Carcharhinus falciformis*), Whale Sharks, White Sharks, and Giant Manta Rays, are particularly susceptible to entanglement as they feed in frontal zones, where huge quantities of drifting rubbish also accumulate.

Plastic waste, regardless of whether it was originally a fishing net or a toothbrush, does not disappear over time – rather, it will break up into smaller and smaller pieces. These tiny, toxic pieces of plastic, now ubiquitous throughout the ocean, are impossible for animals to avoid. While plastic fragments have been found in the stomachs of many sharks and rays, accidental ingestion by large filter-feeders such as Manta and Devil Rays (*Mobula* spp.), Whale Sharks, and Basking Sharks (*Cetorhinus maximus*) is a particular concern.

These species feed in areas where zooplankton are swept together by ocean currents and tidal flows; unfortunately, drifting plastics are along for the same ride. Studies of plastic fragments at Reef Manta Ray (*Mobula alfredi*) and Whale Shark feeding areas in Indonesia estimated there to be 20,000–449,000 pieces of plastic per km², leading to estimated ingestion rates of up to 63 items per hour for Manta Rays, and up to 137 items per hour for Whale Sharks. Reef Manta Rays were estimated to be ingesting up to 980 g of plastic per kilogram of plankton. Basking Sharks in the Mediterranean Sea were estimated to be ingesting 540 plastic pieces per hour.

Blockages and internal injuries from ingestion can be lethal. Inspection of a dead Whale Shark that washed ashore in Thailand found it had been killed by a single hardened plastic straw that perforated its oesophagus. Dead animals are unlikely to be found in the wild, and are rarely the subject of detailed examinations, so mortalities from plastic have so far only been documented due to unusual circumstances. Two other separate plastic-related deaths in Whale Sharks in Japan were identified because they died in a rehabilitation centre, 201 and 297 days after their respective arrivals, from intestinal damage caused by ingested plastic pieces that were not available to them within the facility.

That said, plastic ingestion by sharks and rays, especially small pieces, will usually result in the fragments passing through the intestinal tract without causing damage. A concern, though, is that individuals will increasingly suffer from malnutrition – such as in the case of Reef Manta Rays in Indonesia, referred to above, where they could be physically 'full' with only 52% zooplankton in their stomach. An additional area of current research is whether ingested plastics will offload pollutants to sharks and rays. Plastics adsorb many of the chemical pollutants listed earlier, such as PCBs, DDT, PAHs, and heavy metals, and can concentrate them up to one million-fold that found in the surrounding water. Upon ingestion, these chemicals can leach into the animals' tissue. In other ocean wildlife groups, such as marine mammals, this is believed to suppress their reproduction. For many species of sharks and rays that are already threatened with extinction, such as the three megaplanktivores listed above, the possibility of a similar inhibitory effect is a significant concern.



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HUMAN HEALTH

All of us are exposed to environmental pollutants throughout our lifetime. Humans are, effectively, apex predators, and our diet is a significant exposure pathway for bioaccumulation. Around two billion people live within 100 km of the coast, and seafood is an important part of the diet for many coastal communities, particularly where the primary industry is fishing. Meat and secondary products deriving from sharks and rays (e.g., fins or gill plates) are consumed and used worldwide and therefore the high concentrations of pollutants found in these species pose a risk to human health.

Biomonitoring studies on fishing communities have detected elevated concentrations of organic pollutants and mercury. A single serving of shark meat (113 g for adults and 11-year-olds; 28 g for 2-year-olds) can expose adults and children to over three times the maximum recommended daily mercury consumption limit. The US Food and Drug Administration and Environmental Protection Agency have recommended that people avoid eating shark meat entirely. Their current daily recommended limit is 980 ng g^{-1} for mercury, but a recent study found the average mercury concentrations in sharks actually exceed this value by 66% (1670 ng g^{-1}). People consuming sharks from the orders Carcharhiniformes and Lamniformes are at even greater risk, as the average mercury concentration in these generally large-bodied species exceeded 4000 ng g^{-1}. High mercury levels have been documented in Blue Sharks, Silky Sharks, Dusky Sharks (*Carcharhinus obscurus*), Hammerheads (*Sphyrna* spp.), Shortfin Mako, Threshers (*Alopias* spp.), and Oceanic Whitetip Sharks (*Carcharhinus longimanus*). In addition, exposure to other pollutants found in shark tissue, such as PCBs and dioxins, has been linked to cancer, liver and kidney damage, immunosuppression, reproductive defects, and endocrine disruption. Pregnant women and young children are especially vulnerable to these health risks.

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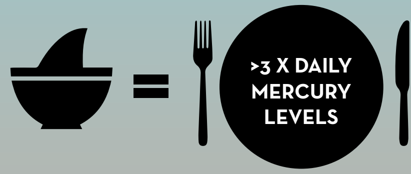

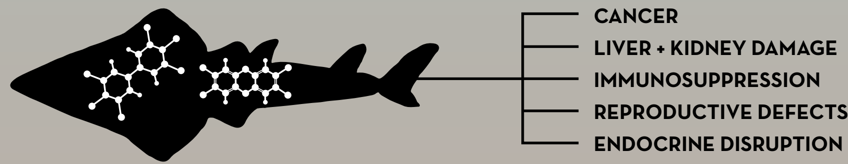

Exposure to other pollutants found in shark tissue, such as PCBs and dioxins, has been linked to serious health conditions.

Shark and ray meat is increasingly consumed in many coastal communities around the world | Rima Jabado

LOOKING FORWARD

On a population level, pollution is likely to have a minor, but chronic, effect on threatened sharks and rays. Unfortunately, it is getting worse. Large predatory sharks tend to be long-lived, which makes them susceptible to bioaccumulation of pollutants over time. They also biomagnify any contaminants found within their prey. Plankton-feeding sharks and rays are particularly susceptible to plastic pollution and oil spills. All migratory sharks and rays are threatened by ghost fishing gear. Substantial effort is required to stop toxic chemicals, heavy metals, and waste materials from entering the ocean. End-point measures, such as beach clean-ups to remove plastic waste, are an important part of meeting the challenge, but are not themselves a complete solution. To achieve meaningful reductions on a global level, the use of disposable plastics within the supply chain needs to be phased out, and waste management infrastructure improved so that less rubbish reaches the ocean in the first place.

Shark and ray meat and other products commonly contain toxic loads of mercury and other pollutants. Consumers need to be made aware of this, as it presents a significant health risk. Regular testing of shark and ray products by food safety agencies can assist here. A pause on the local sale and export of shark and ray meat and other derivatives, if pollutant levels exceed recognized safe levels, also presents an immediate commercial imperative to help identify and reduce pollution inputs, thereby helping to maintain sustainable fisheries for the species and areas in which this is possible.

To improve the overall situation for sharks and rays, specifically, it is important to identify and prioritize the areas in which threatened species are most likely to be affected. By investigating which pollutants are creating problems in these locations, and the likely sources of contamination, we can in some cases turn a global issue into a relatively local one. Party and Non-Party Range States to CMS will thereby be able to identify opportunities for conservation within their own waters, and for regional partnerships.

Fishers sorting plastic waste from fishing nets in Visakhapatnam, India
Srikanth Mannepuri | Ocean Image Bank

FURTHER READING

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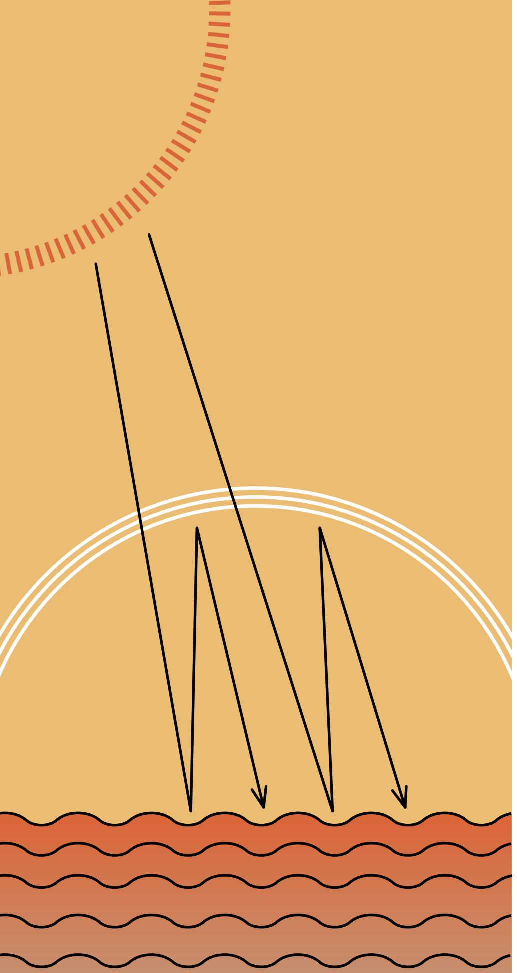
THE IMPACTS OF CLIMATE CHANGE ON SHARKS AND RAYS

DR. SIMON J. PIERCE



The ocean is presently absorbing an estimated 90% of the heat trapped in the earth's atmosphere, causing a clear rise in surface temperatures.

CLIMATE CHANGE IS A LONG-TERM SHIFT IN GLOBAL OR REGIONAL CLIMATE PATTERNS. THIS INCLUDES CHANGES IN AVERAGE MEASUREMENTS OF TEMPERATURE, WIND, HUMIDITY, SNOW, AND RAINFALL OVER A LONG PERIOD OF TIME.

Human-influenced climate change is an existential threat to many shark and ray species. Most sharks and rays are cold-blooded (ectothermic) animals, with their biology and metabolism dictated by the ambient water temperature. The ocean is presently absorbing an estimated 90% of the heat trapped in the earth's atmosphere, causing a clear rise in surface temperatures.

Changes in sea surface temperatures are creating newsworthy changes in shark distribution. Warm water species like the Whale Shark (*Rhincodon typus*) have been reported in mainland Europe (Portugal) for the first time, Hammerhead Sharks (*Sphyrna spp.*) and Bigeye Thresher Shark (*Alopias superciliosus*) are increasingly common in Britain, and Tiger Sharks (*Galeocerdo cuvier*) are being caught off Canada in the north and Tasmania, in Australia, to the south.

At the same time, though, some tropical waters are becoming uninhabitable for sharks and rays, while cooler-water species are feeling the squeeze as their habitats contract.

Latitudinal shifts in marine ecosystems are a gradual process, but many effects of climate change are moving much faster. Sea level rise is inundating coastal regions. Marine heatwaves and tropical storms are becoming more frequent, and more severe. Deoxygenated 'dead zones' in the ocean present a barrier to wildlife migrations, while acidification is degrading coral reef ecosystems. These are shared threats to sharks, rays, and people.

The long evolutionary history of sharks and rays, and their ancestor's persistence through several mass extinction events, provide us with some insights into the species that may be most at risk of human-induced climate change. This time, however, their challenges are compounded by overfishing and habitat modification, that has already depleted shark and ray populations. In this fact sheet, we explore the main threats to sharks and rays from climate change, particularly those listed on the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), and how we can shield the most at-risk species.

Cover | Eagle Ray over coral reef
Single Fin Photo | Ocean Image Bank

SHIFTING POPULATIONS

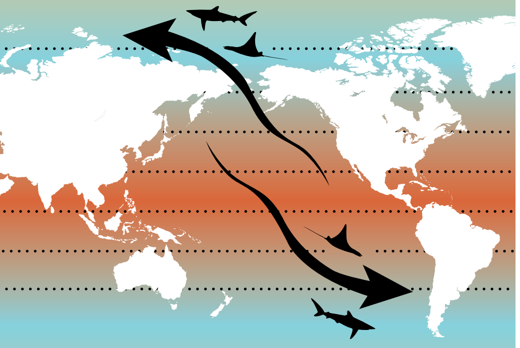
Ocean temperature has a direct effect on physiological and metabolic functions in sharks and rays, including digestion, growth, and reproduction. That makes it difficult to generalize how sharks and their relatives, a diverse group of around 1,250 species, will respond to rising ocean temperatures; it depends on their preferred habitats, diet, and swimming ability, to note just a few factors.

Projections of how each species will be affected by climate change generally rely on modelling their contemporary habitat use, based on fisheries, sightings, or tracking data, then predicting how these habitats will shift based on future change scenarios. Unsurprisingly, given the lack of data available for many sharks and rays, these predictions are only available for a small number of species.

Some open ocean species, like migratory Blue Sharks (*Prionace glauca*), Shortfin Mako Sharks (*Isurus oxyrinchus*), Silky Sharks (*Carcharhinus falciformis*), and Oceanic Whitetip Sharks (*Carcharhinus longimanus*), can swim towards the poles to maintain their optimal temperature environment. However, pelagic sharks generally have a relatively narrow preferred temperature range. For example, Oceanic Whitetip Sharks spend over 95% of their time within 2°C of the surface water temperature. Pelagic species are all active hunters and, as such, they have naturally high metabolic rates. As water temperature increases, the shark's metabolism does too. They have to swim faster to deliver sufficient oxygen to their bodies, eat more to supply energy, or suppress their growth and reproduction to compensate. Even at the best of times, these sharks live on an energetic knife-edge. Similarly, Giant Manta Rays (*Mobula birostris*) also appear to be sensitive to high temperatures, preferring surface waters under 29°C. While these species can expand their distribution into cooler waters to adjust to rising ocean temperatures, large areas of tropical surface waters are becoming unhabitable, resulting in an overall range contraction for sharks and rays globally.

Warming oceans are increasing the strength and frequency of acute marine heatwaves, such as the El Niño Southern Oscillation (ENSO). These events provide additional insight into likely species- and community-level effects of longer-term climate change. A case study from Cocos Island off Costa Rica, based on 27 years of diver-recorded shark and ray sightings, investigated the effects of ENSO events on the Scalloped Hammerhead (*Sphyrna lewini*) which has one of the highest metabolic rates among all sharks. This species, which is Critically Endangered according to the IUCN Red List of Threatened Species, had the strongest response to temperature change in the monitored community. Predicted individual shark counts declined by 10% for a 1°C increase in water temperature, and by 40% with an increase from 25 to 30°C. The probability of observing hammerhead schools (>50 individuals) was 43% more likely at 25°C than at 30°C. During cooler La Niña years, there were twice as many Scalloped Hammerheads present at the island, and schooling behaviour was 118% more likely during strong La Niña events than during strong El Niño conditions.

School of Scalloped Hammerheads (*Sphyrna lewini*) in the Eastern Pacific Ocean | Simon Pierce



Since the 1950s, ocean surface warming has shifted marine taxa and communities pole-ward at an average of 59 km per decade.

CLIMATE REFUGEES

Many sharks and rays are dependent on particular habitats, such as coral reefs, which are not continuous. Walking Sharks (*Hemiscyllium* spp.), found only on shallow reefs in the tropical Indo-Pacific, can only shift their range if there is additional reef habitat with suitable environmental conditions that is close enough for these small sharks to swim to. Thermal stress on coral reefs is already evident, such as the well-publicized recent bleaching events on the Great Barrier Reef in Australia, where the 2016–2017 event affected two-thirds of this huge reef system.

Some sharks and rays have very small natural or remnant ranges, such as the Maugean Skate (*Zearaja maugeana*), now found only in a single harbour in Tasmania, and the New Caledonia Catshark (*Aulohalaelurus kanakorum*), thought to be restricted to southern New Caledonia. Others appear to have hugely reduced ranges due to overfishing, such as the Clown Wedgefish (*Rhynchobatus cooki*), which has solely been recorded from the Lingga Archipelago in Indonesia in recent years, and the False Shark Ray (*Rhynchorhina mauritaniensis*) which is believed to be restricted to the waters of a small bay in the Banc d'Arguin National Park in Mauritania. Species in this situation can be left stranded in habitats that push their physiological tolerances. It is analogous to the situation on land, where high-altitude species have been forced higher and higher up mountains, until they simply run out of space to live. Similarly, there is concern for Critically Endangered species whose ranges have been heavily fragmented by overfishing and habitat loss, such as the Angelshark (*Squatina squatina*) and Common Guitarfish (*Rhinobatos rhinobatos*). These species use warm, shallow protected waters in the eastern Atlantic and Mediterranean as nurseries to speed the development of their pups. The Angelshark was historically known for coastal migrations into northern Europe, where it is now mostly absent. The small contemporary population, decimated by overfishing, is now isolated in pockets of suitable habitat. The species is most commonly sighted in the Canary Islands, where its options for temperature-related adaptive movement are limited by the deep trenches between islands and between the island chain and the African continent.

This emphasizes the importance of maintaining habitat continuity for threatened populations by safeguarding movement corridors between suitable areas, and preserving critical habitats, such as the coastal nurseries used by the pups of many shark and ray species. Inshore and estuarine nursery areas are highly susceptible to climate change. Sea level rise may, in some cases, expand these areas through the inundation of marshes. However, increased water depth can also reduce the light required by seagrass meadows to maintain photosynthesis, reducing the availability of seagrass-associated prey species for young sharks and rays. Increasing water temperatures are exacerbated by sun exposure in these shallow environments, with associated deoxygenation (discussed in the next section), while coastal areas are susceptible to damage from storms.

In particular, heavy rains expose estuarine habitats to increased runoff and freshwater input. Juvenile Bull Sharks (*Carcharhinus leucas*), which are well-known for being able to move between fresh and saltwater environments, often live in rivers for their first few years of life. Studies of young Bull Sharks in the Logan and Albert Rivers in Australia found that flooding events caused rapid drops in both salinity and the water's dissolved oxygen content that exceeded their ability to adapt, causing several tagged sharks to permanently leave the system, increasing their risk from fishing and predation. Public reports of dead sharks at the Logan River mouth after the flood suggest that not all survived the flood. As storms become fiercer, and more frequent, such events are projected to increase.

OCEAN DEOXYGENATION

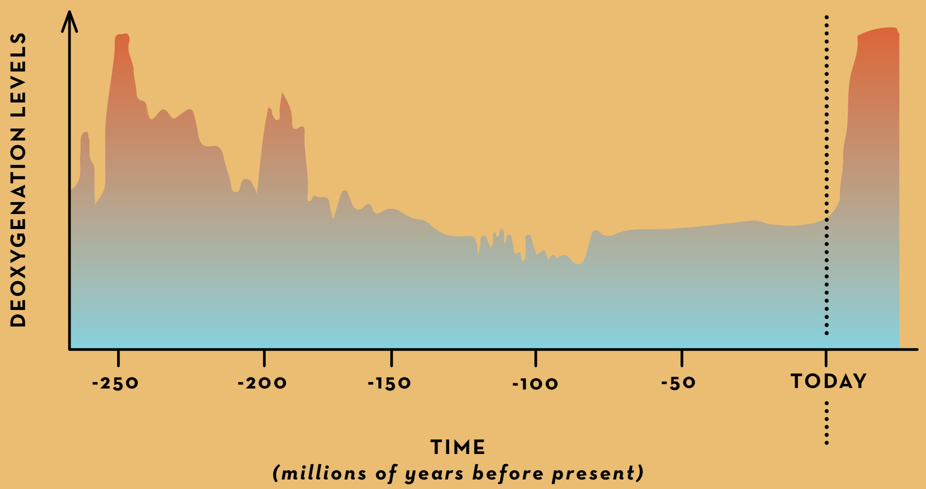
Accelerating water deoxygenation, now seen in all oceans, is one of the most significant ecological consequences of climate change. Projected deoxygenation levels towards the end of this century will mimic conditions that were last found during the end-Permian Period (about 250 million years ago), when a collapse of suitably aerobic habitat caused the largest marine extinction in geological history. In previous mass extinction events, large cold-blooded animals and top predators were among the worst-affected animals by ocean warming and associated deoxygenation. Sharks, of course, are among the largest animals in the marine environment.

Oxygen is less soluble in warmer water, which poses a serious problem for migratory sharks. Open ocean species must constantly swim to maintain the flow of oxygenated water over their gills so they can, in turn, deliver oxygen to their muscles and organs. By itself, their constant swimming requires a lot of energy and oxygen. As water temperature increases, the shark's metabolism does too, but their available gill surface area for extracting oxygen is a physical constraint.

Sharks and rays live in a three-dimensional habitat, so they can normally use depth to avoid high surface temperatures. Blue Sharks, for instance, are one of the world's most widely distributed cold-blooded animals, capable of swimming across entire ocean basins and diving to over 1600 m depth. With that comes a high tolerance for environmental variation, as they can naturally be exposed to temperatures of 4–30°C. During long-distance migrations, they often remain at ~400 m depth to reduce their energy costs by staying in cooler water. Their metabolic rate at this depth is estimated to be only 40% of that in warmer surface waters. However, they still require a minimum oxygen level. A reduction in the oxygen content of surface waters, due to heating, is magnified at depth, as oceanic bacteria use up a high proportion of the remaining oxygen. In some regions, this has created permanent 'oxygen minimum zones' (OMZs) between 200–1,000 m depth, in which oxygen levels are too low for pelagic sharks to use routinely. As the oceans warm, OMZs are expanding both horizontally and vertically. In the eastern tropical Atlantic, the OMZ has been expanding for the past 50 years, increasing in thickness (depth range) by 85% between 1960 and 2006.

Recent observations have detected such low oxygen content in some oceanographic features within this area that they are referred to as 'dead zones'. Tracking data of Blue Sharks in this region found that their average maximum dive depth in the OMZ was 40% less than the mean depth outside the area, with a greatly reduced frequency of deep diving (to below 600 m) while inside the OMZ. Restricted dive profiles in OMZs have also been documented from White Sharks (*Carcharodon carcharias*) and Shortfin Mako in the eastern Pacific Ocean.

Deoxygenated zones reduce the habitable space for pelagic sharks and compress their vertical movements. That makes the sharks more susceptible to capture in open ocean fisheries. Blue Sharks make up ~90% of the catch of pelagic sharks in the Atlantic, and their fins are the most commonly traded in international markets. Longline catches of Blue Sharks around the eastern Atlantic OMZ were higher inside than outside it, primarily in areas where shark dive depths were predicted to be shallower, based on the tracking data. As OMZs increase in size, restricting sharks to their edges, or to staying close to the surface if they have to cross these biological deserts, their already depleted populations become more catchable by industrial fisheries.

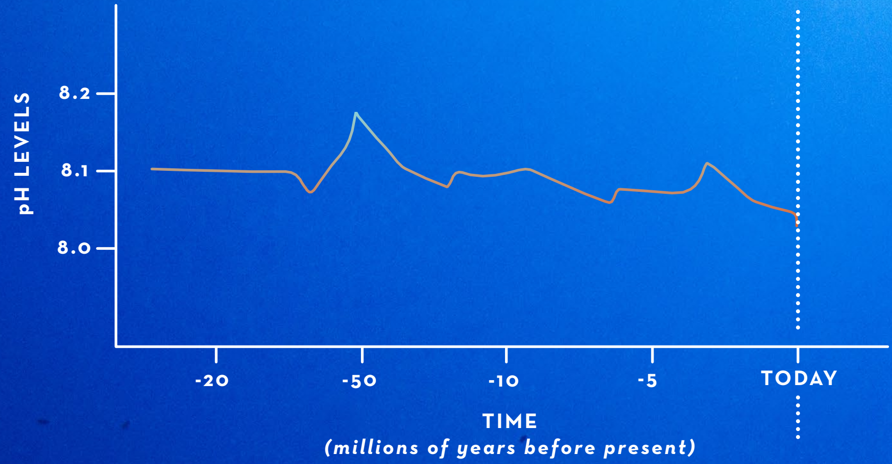


Projected deoxygenation levels towards the end of this century will mimic conditions that were last found during the end-Permian Period (~250 million years ago), when a collapse of suitably aerobic habitat caused the largest marine extinction in geological history.

OCEAN ACIDIFICATION

With levels of atmospheric carbon dioxide on the rise, the ocean is an increasingly large sink, absorbing up to 30% of this atmospheric carbon. When carbon dioxide dissolves into seawater, it forms carbonic acid (H_2CO_3). This reduces the ocean's pH level, which is naturally slightly basic (meaning pH>7). 'Ocean acidification' is the term used to describe the shift of ocean water closer to pH-neutral. The decreasing pH of the ocean reduces the amount of calcium carbonate in the water, which is used by many marine animals to build their skeletons and shells – including shellfish, many of which are eaten by sharks and rays, and corals, which provide vital habitat for many species.

The ocean has already increased around 30% in acidity since records began, and current estimates indicate that the ocean pH level at the end of this century will be the lowest in more than 20 million years. Generally, laboratory-based research has suggested that sharks and rays show some physiological tolerance to elevated carbon dioxide levels, though there can be negative effects on growth and metabolism through compensatory responses, and a reduced ability to locate food through olfaction. The effects of acidification on larger, more mobile species are yet to be investigated. At this stage, the primary effects of acidification on sharks and rays are thought to be through habitat loss, particularly for reef-associated species like the Porcupine Ray (*Urogymnus asperrimus*), while many prey species are dependent on calcium carbonate, which will of course indirectly affect sharks and rays too.



The ocean has already increased around 30% in acidity since records began, and current estimates indicate that the ocean pH level at the end of this century will be the lowest in more than 20 million years.

Grey Reef Sharks (*Carcharhinus amblyrhynchos*) on coral reef in French Polynesia
Hannes Klostermann | Ocean Image Bank

LOOKING FORWARD

Some sharks and rays can adapt or relocate to cope with ocean warming, either by moving into deeper water or through latitudinal shifts. Unfortunately, many habitat specialists who cannot relocate – such as freshwater, estuarine, and coral reef species – are already struggling with overfishing and environmental degradation. Climate change is a multiplier for the existing stressors on threatened sharks and rays.

There are many actions that governments, businesses, and individuals can and should take to reduce climate change. While working towards these measures, we still need to mitigate the present and projected impacts on sharks and rays. There are two main components to this. First, we can ensure that species have safe areas to move to if their preferred habitats become uninhabitable. Second, by improving their conservation status, we can maximize their resilience to change.

Signatories to CMS and the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU) can lead on both of these initiatives. Migratory sharks and rays require secure habitats that are large enough to span the depths and latitudinal ranges that allow for adaptive movements, and for swimmable corridors to be maintained between such habitats. As an example, the Galapagos Marine Reserve (Ecuador) and Cocos Island National Park (Costa Rica) were both significantly expanded in 2021, with a protected 'swimway' created between these iconic UNESCO World Heritage Areas to safeguard the migratory sharks, rays, and other species that move between them. Proactive management arrangements like this will often extend across national and international boundaries, emphasizing the need for cooperation. Coastal species could also benefit from the protection and maintenance of healthy ecosystems at the poleward extremes of continents, such as the Cape Region of South Africa and in southern Australia, to provide safe refuge for the animals that are forced to move by ocean warming.

Overfishing is a more immediate threat than climate change for most sharks and rays. However, unfortunately, these threats are synergistic; climate change can increase migratory species' susceptibility to fishing. Scenario planning has begun for sharks in certain locations, such as the Tope Shark (*Galeorhinus galeus*) in southern Australia, in which climate change impacts and fishing mortality are projected to constrain the species to its current Critically Endangered level without further conservation efforts. For pelagic sharks, like the Blue Shark, Shortfin Mako, and White Shark, regional management will have to consider and mitigate the effects of ocean deoxygenation increasing catch rates for these threatened species. Spatial management, such as large offshore protected areas, may be an option for regions where OMZs are present.
To ensure the resilience of threatened species going forward, and to prevent more species from declining to that perilous state, we need to turn climate change into climate recovery.

Epaulette Shark (*Hemiscyllium ocellatum*) from Australia | David Clode

FURTHER READING

IPCC Sixth Assessment Report. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/.

Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA, Finucci B, Pollock CM, Cheok J, Derrick DH, Herman KB (2021) Current Biology 31(21): 4773–87.

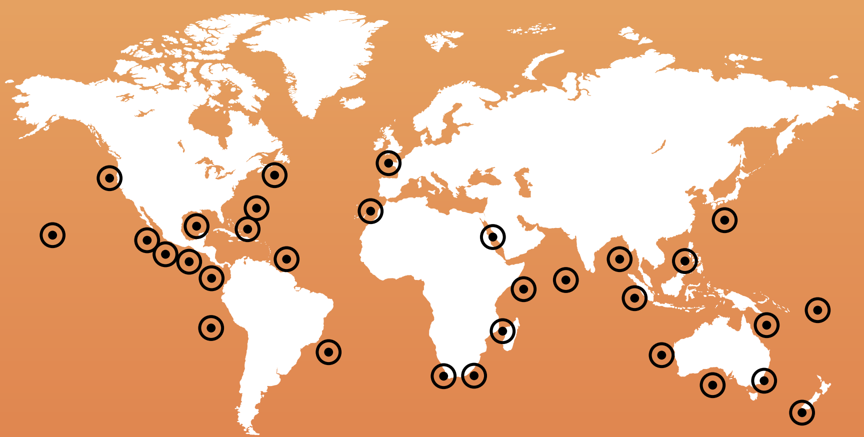
Powering ocean giants: The energetics of shark and ray megafauna. Lawson CL, Halsey LG, Hays GC, Dudgeon CL, Payne NL, Bennett MB, White CR, Richardson AJ (2019) Trends in Ecology and Evolution 34(11): 1009–21.

THE IMPACTS OF TOURISM ON SHARKS AND RAYS

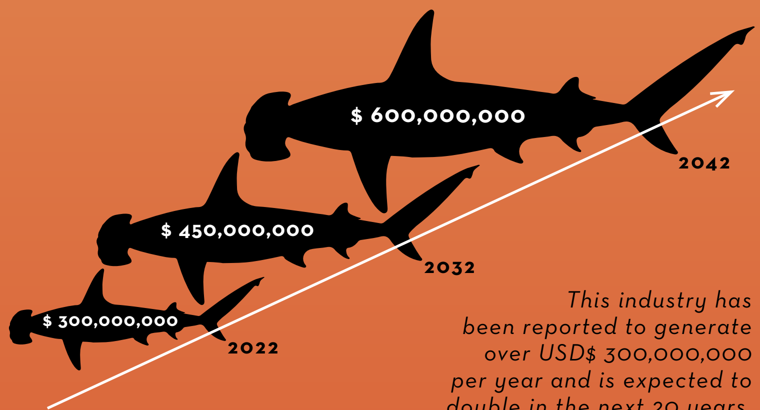
DR. SIMON J PIERCE
RYAN CHARLES

1,000,000

Over one million people join tours annually to dive or snorkel with sharks and rays in their natural habitat.



Shark tourism occurs in more than 40 countries, focused on around 50 shark and ray species.



This industry has been reported to generate over USD$ 300,000,000 per year and is expected to double in the next 20 years.

SHARK TOURISM IS DEFINED HERE AS VIEWING, DIVING, OR SNORKELLING WITH SHARKS AND RAYS IN THEIR NATURAL HABITAT.

Shark and ray encounters are one of the fastest-growing sectors in the wildlife tourism industry. Over one million people join tours annually to dive or snorkel with sharks and rays in their natural habitat. Shark tourism occurs in more than 40 countries, focused on around 50 shark and ray species, including many of those listed on the Convention on the Conservation of Migratory Species of Wild Animals (CMS). This industry has been reported to generate over USD$ 300,000,000 per year and is expected to double in the next 20 years.

Many migratory sharks and rays are increasingly rare, due to overfishing and other human pressures, and are naturally cautious around the unfamiliar setting of divers and boats. To ensure reliable viewing, operators will feed or otherwise attract sharks and rays to the boat or dive site, or alternatively may take the tourists to swim or dive with these animals at feeding areas, cleaning stations, or other places that these animals visit regularly.

Shark tourism is a relatively new industry, with a low barrier to entry in many countries, and can quickly outpace management capacity. While the terms 'shark diving ecotourism' and 'shark tourism' are often used interchangeably, the word 'ecotourism' implies that activities are ecologically sustainable, directly contribute to species and habitat conservation, and provide tangible benefit to the local community. Whether shark tourism can truly be considered ecotourism varies between sites and species; some sites meet this definition, but others do not.

When conducted responsibly, shark tourism can provide a range of benefits, from economic development to increased legal protections for threatened species and their habitats. However, the rapid expansion of this industry can also lead to disruption of shark and ray behaviours, increased injuries to the focal species, and degraded habitat. In this fact sheet, we explore the potential for negative impacts from shark tourism, particularly on CMS-listed species and those listed on the Memorandum of Understanding on the Conservation of Migratory Sharks (Sharks MOU), and how they can be mitigated or avoided.

Cover | Grey Reef Sharks (*Carcharhinus amblyrhynchos*) at Osprey Reef, Australia | David Robinson

Shortfin Mako (*Isurus oxyrinchus*) with snorkeller
in Baja California Sur, Mexico
Hannes Klostermann | Ocean Image Bank

ATTRACTING AND FEEDING SHARKS

Most sharks and rays are seldom seen in the wild. To encourage them to stay visible to divers, it is common for operators to use bait or other attractants to attract and aggregate these species. Tactics can range from hand-feeding Whale Sharks (*Rhincodon typus*) to using dive torches to excite zooplankton, which are then preyed upon by Reef Manta Rays (*Mobula alfredi*), or even playing heavy metal music through underwater speakers to attract White Sharks (*Carcharodon carcharias*). Two well-studied examples of shark tourism are cage diving with White Sharks, likely the most regulated subset of the industry, and feeding Whale Sharks, which has minimal management in place.

White Sharks are large apex predators and, as such, they can be potentially dangerous to people. To create a safe tourism experience, a protective cage is deployed to allow divers or snorkellers to observe the sharks from underwater. White Shark cage diving began in the 1970s in South Australia and has subsequently been developed in the USA, South Africa, Mexico, and New Zealand. Tourism focuses on areas where the sharks are naturally found in relatively high densities, often near seal colonies which are important prey for White Sharks. To bring the sharks close enough for underwater viewing, operators typically use some combination of scent (generally small pieces of fish) and baits, seal-shaped decoys, or sound-based attractants, depending on local regulations and operator preferences.

Earlier in the industry's development, some operators would drag baits over the cage to encourage the sharks to closely approach the tourists. This led to minor injuries to the sharks if they inadvertently struck the cage or, worse, became entangled in grating or lines. Managers and operators have consistently tightened legal and informal regulations to avoid such practices over time.

There has always been a high level of public and management interest on the effects of tourism activities on White Shark behaviour and biology. This is partly due to their threatened status, as a globally Vulnerable species according to the IUCN Red List of Threatened Species, but largely because vocal concerns have been raised about the potential for sharks to associate watergoers with food in other situations. To minimize the possibility of habituation, operators are not allowed to feed the sharks; instead, baits are removed from the water as sharks approach. White Sharks are accomplished ambush hunters, and sharks do sometimes manage to consume the baits, so the amount of bait that can be used in a day or trip is also regulated to incentivize operator attentiveness.

Tagging studies have demonstrated that White Sharks do increase their activity level while around tourism vessels, expending additional energy. But, as there is little or no food reward, more resident sharks appear to become increasingly disinterested and less inclined to approach tourist boats over time. However, such behaviours are variable, with other individuals continuing to approach boats. Biochemical studies have found no overall change in diet or decline in body condition in the White Sharks sampled from tourism vessels. There may be some effect on the sharks' social dynamics, with larger sharks showing dominance behaviours and possibly increased aggression in the face of perceived competition from other White Sharks, but clear patterns have not been documented.

Cessation of tourism activities at the Neptune Islands in South Australia, as part of the health response to the COVID-19 pandemic, led to a 51-day break in White Shark tourism activities, the longest gap in 12 years. Long-term passive tracking of tagged White Sharks through this period allowed for an opportunistic analysis of changes to shark residency and movements. The absence of tourism vessels had no effect on White Shark activity or residency, indicating that the presence or absence of tourism makes little difference to the sharks.

Snorkelling and diving with the filter-feeding Whale Shark species has become a highly popular tourism experience in the few locations they predictably aggregate. While Whale Sharks are often thought of as strict planktivores, they will also target small fishes, and fishers at a few sites in Indonesia and the Philippines began feeding Whale Sharks that were attracted to their fishing activities. This has developed into a major industry over the past decade, with the best-known and most accessible site at Oslob, on the island of Cebu in the Philippines.

Oslob has become one of the most popular tourist destinations in the country, attracting hundreds of thousands of people each year to view the sharks and creating significant economic benefits for the community.

Cage diving with Great White Sharks (*Carcharodon carcharias*) off Guadalupe Island, Mexico | Simone Caprodossi

The Whale Sharks are hand-fed in a small viewing area close to shore that is demarcated with buoys. Operators paddle most tourists out to the sharks in small outrigger canoes, where the sharks are individually fed from other canoes. Tourists can either view the sharks from the boat, snorkel, or dive with them.

While Oslob is a natural seasonal migratory corridor for Whale Sharks, a small number of sharks have become highly habituated to being fed, appearing daily over months to years. Studies on 208 individual sharks over three years of monitoring found a diversity of residence patterns, with 21 seasonally resident and nine year-round resident sharks, suggesting some degree of dependency in the latter group. As sharks become more resident, they become highly tolerant of boats, which increases their risk of propeller injuries; lacerations were present on 28% of the sharks, with overall scarring rates much higher than at other Whale Shark tourism destinations. Sharks accumulated injuries and abrasion damage (due to regularly bumping boats while feeding) during residency periods. As the feeding activities take place in warm shallow water, the sharks often dive into deeper water off the site to cool down after feeding ceases for the day. Tagging studies estimate a 7% higher metabolic rate for sharks that frequent the area due to the time spent in warm water and constant suction-feeding the sharks employ. The long-term effects of higher injury rates and daily energy use remain unknown at this point.

Aside from the clear designation of the interaction zone, there is little regulation of tourism activities at the site. While in-water encounter guidelines exist, enforcement is low, with 93% of tourists breaching the directives by approaching within 2 m of the sharks, often touching them. Tourist surveys found that 96% of them felt crowded by boats in the viewing area, while a carrying capacity study concluded that Oslob is “overcapacity”, in terms of swimmers, and “greatly overcapacity” in the number of boats present.

The risk posed by shark tourism activities will largely be dictated by the ecology of the species in question. Many migratory sharks and rays are wide-ranging; using bait as an attractant for Blue Sharks (*Prionace glauca*) or Shortfin Makos (Isurus oxyrinchus), which often swim hundreds of kilometres a week, is unlikely to result in habituation or dependency. Some long-running shark-feeding sites, such as the well-researched seasonal aggregation of Bull Sharks (*Carcharhinus leucas*) at Shark Reef in Fiji, have demonstrably had negligible long-term effects on shark behaviour and diet. Less mobile species can show more evidence of impact. Southern Stingrays (*Hypanus americanus*) have been fed at Grand Cayman in the Caribbean since the 1930s by fishery discards, and almost continuously for tourism purposes over the past thirty years. Here, some individual stingrays are highly resident, with 37 animals attending the feeding site for at least a decade. Large stingrays, particularly adult females, dominate smaller females and males in the competition for food, leading to increased conflict and injuries in this aggregation, as well as higher parasite loads and stress markers. Biochemical studies have demonstrated that the squid used as food makes up a large proportion of the diet of the most resident individuals, which remain close to the feeding site over extended periods, and switch from primarily nocturnal to being most active in the daytime.

Whale Shark (*Rhincodon typus*) tourism at Oslob, Philippines | Simon Pierce

Tiger Shark (*Galeocerdo cuvier*) and divers
Jett Britnell | Ocean Image Bank

However, the stingray population at the site has continually increased in recent years, coinciding with the legal protection of Southern Stingrays in the Cayman Islands. Resident stingrays have high long-term survival rates, so the overall negative impacts of this tourism appear to be minor.

Newer sites, with minimal legal or self-regulation in place, can be prone to 'overfeeding', which has a higher chance of creating dependency, associated negative health outcomes, and behavioural changes in the animals. The same is true for discards from fishing activities, which introduce large quantities of shark food into specific sites on a regular basis. While such activities are unlikely to negatively affect the overall conservation status of the focal species, it is important to safeguard the welfare of local shark and ray populations. Where food is being provided, it should be high-quality, part of the animal's natural diet, and distributed at a minimal level.

It is important to safeguard the welfare of local shark and ray populations. Where food is being provided, it should be...

HIGH QUALITY

PART OF THE ANIMAL'S NATURAL DIET

DISTRIBUTED AT A MINIMAL LEVEL

PRESSURE ON KEY HABITATS

Most shark and ray tourism is based on visiting sites where these animals can be reliably seen in the absence of attractants. This tourism can vary from shore-based snorkelling to multi-day expedition-style dive trips to see pelagic sharks at remote volcanic islands and seamounts. In general, these activities are regarded as low impact on sharks and rays, but the regular appearance by people in important shark and ray habitats, such as feeding areas, cleaning stations, or reproduction sites, creates the risk of disturbing the animals or disrupting important natural behaviours. Where there is a near-constant human presence, there is a threat of chronic stress and disruption. Proactive management is needed to avoid negative effects.

Monad Shoal, a large seamount off the island of Malapascua in the Philippines, is one of the only sites where Pelagic Thresher Sharks (*Alopias pelagicus*) are routinely seen by divers. Monad Shoal acts as a health and hygiene stop for the sharks, where small wrasse inhabit 'stations' on certain reef structures. Sharks accumulate external parasites over time, which can cause chronic disease, developmental problems, and respiratory issues if they attach to the gills. Normal wear and tear from the sharks' active predatory lives also result in minor injuries and dead skin, which can lead to infection. The wrasse eat parasites and dead tissue, providing a useful service to the sharks – while gaining an easy meal themselves. The sharks visit the stations regularly, with at least some sharks present almost every day, creating a popular attraction for shark tourists.

The cleaning stations themselves are not immediately obvious, as they are simply patches of reef inhabited by small wrasses. This makes them susceptible to physical damage from inexperienced divers, by accidentally breaking off coral or resting on the stations. Close approaches by divers also disturb the sharks, which circle slowly around the stations to allow the wrasse to stay with them. The first cleaning stations to be found, at ~15 m depth on the top of Monad Shoal, were physically damaged by divers and the cleaner fish abandoned the sites. Deeper cleaning stations on the edge of the Shoal have now had heavy blocks put in place around them, with ropes linking the blocks to fence off the cleaning areas while also providing a convenient handhold for divers to use while viewing the sharks. Now, divers can watch the sharks clean from an appropriate distance, while the Thresher Sharks and cleaner fish maintain unhindered access to the site. A similar solution has been developed for a cleaning station for Reef Manta Rays (*Mobula alfredi*) at a popular dive site, 'Manta Sandy', in Raja Ampat in Indonesia. Here, a line of rocks has been placed parallel to the cleaning station to ensure that divers have a clear demarcation of an appropriate distance to the Manta Rays.

Darwin and Wolf islands, in the far north of the Galapagos archipelago in the Eastern Pacific, share a large migratory population of Scalloped Hammerhead Sharks (*Sphyrna lewini*) and other species such as Galapagos Sharks (*Carcharhinus galapagensis*).

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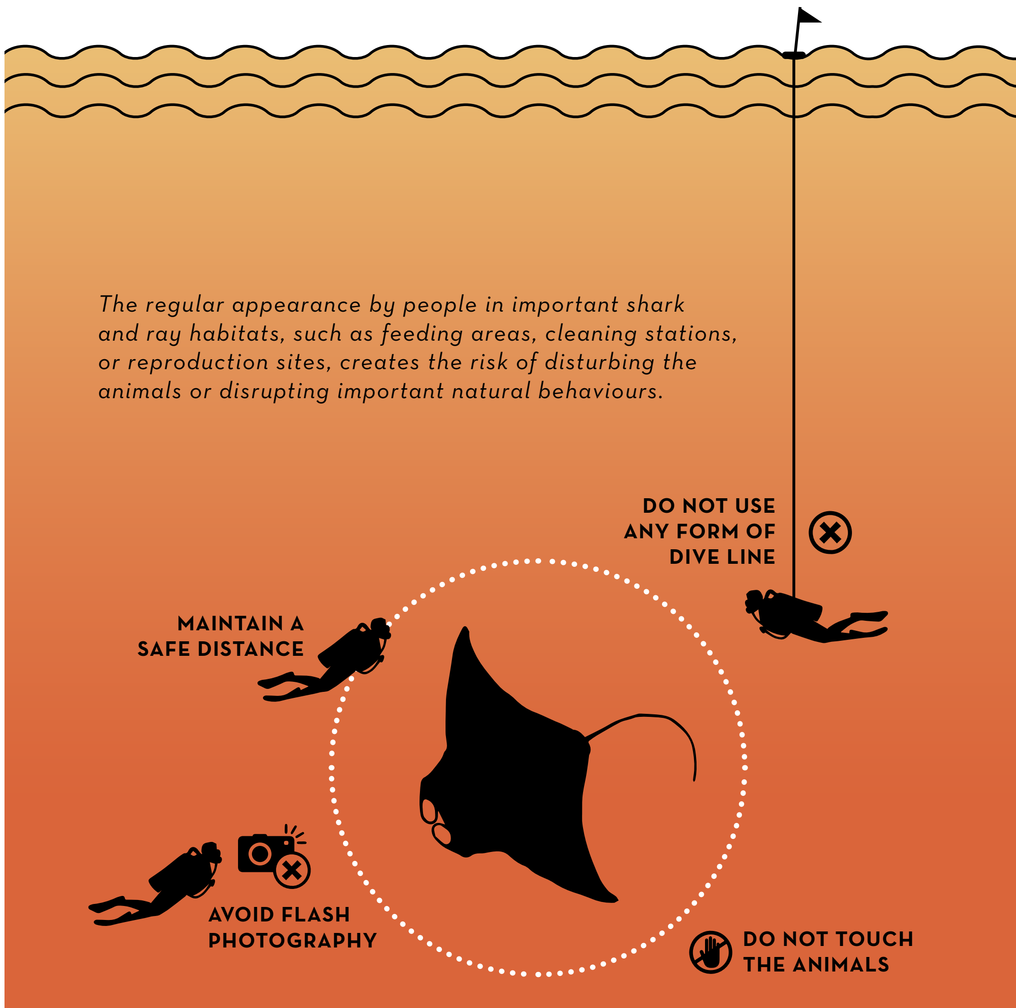
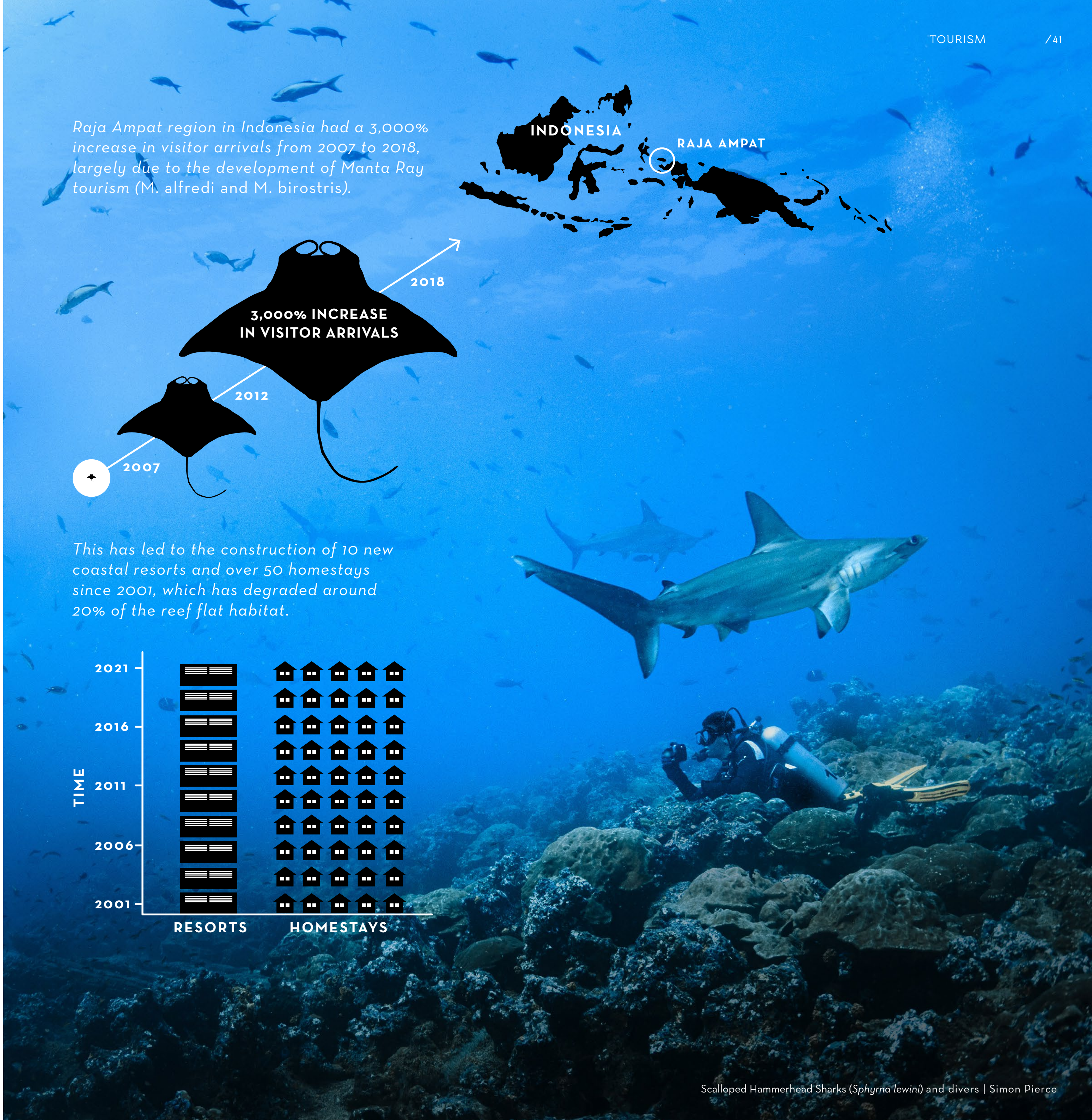


Where there is a near-constant human presence, there is a threat of chronic stress and disruption. Proactive management is needed to avoid negative effects.

During the day, Scalloped Hammerheads school on the upstream side of both these small volcanic islands, where they rest in the water flow, attend cleaning stations, and socialize, before embarking on night-time foraging missions. Scalloped Hammerheads are a shy species that will seldom approach divers, presumably due to the breathing noise and streams of bubbles. To minimize disturbance on this Critically Endangered species, small groups of tourist divers are carefully briefed prior to dives, and actively led underwater by trained guides. Divers are brought to suitable viewing areas, depending on the location of the shark schools, whereupon the divers take up static positions amongst the large boulders. This avoids disturbance to the sharks, as the guides ensure the dive groups do not approach the open-water cleaning areas at these sites. The divers in turn get to unobtrusively observe the natural behaviours of the sharks.

Habitat modification as a result of shark tourism can be a threat to some species. The Raja Ampat region in Indonesia had a 3,000% increase in visitor arrivals from 2007 to 2018, largely due to the development of Manta Ray tourism (*M. alfredi and M. birostris*). This has led to the construction of 10 new coastal resorts and over 50 homestays since 2001, which has degraded around 20% of the reef flat habitat of The Raja Ampat Epaulette Shark (*Hemiscyllium freycineti*), which is endemic to the region. Resort construction, and associated increase in swimmers and snorkellers, can also disrupt and degrade the shallow-water nursery and foraging areas in reef lagoons used by species including the Blacktip Reef Shark (*C. melanopterus*) in the Maldives and Giant Guitarfish (*Glaucostegus typus*) on the Great Barrier Reef in Australia, respectively listed as Vulnerable and Critically Endangered on the IUCN Red List.



Scalloped Hammerhead Sharks (*Sphyrna lewini*) and divers | Simon Pierce

LOOKING FORWARD

There have been few 'before' and 'after' studies on shark tourism, and the recent development of many sites means there are few longer-term data available on community responses and successful management strategies. Assessing the likely impacts of these operations means dealing with high levels of scientific uncertainty across species, sites, and different operational situations. A high level of engagement with experienced operators will be useful, to understand practical issues and develop effective codes of conduct, along with regular reassessment as more information becomes available.

Many of the most important species in shark tourism are considered globally Endangered, and even Critically Endangered according to the IUCN Red List. None have been driven to this point by tourism. Shark tourism has had minimal impact on shark populations compared to overfishing, habitat loss, pollution, and climate change, which all pose significant threats. However, the precarious state of these species makes it important to avoid chronic impacts that can create additional stress on these animals. Increased interactions with boats, divers, and snorkelers will affect sharks and rays. The extent of these impacts, and whether they affect the welfare of the focal species, is dependent on management at the site, whether voluntarily applied or imposed by regulation.

Some of the world's iconic shark preservation areas, such as Raja Ampat in Indonesia, the Galapagos Islands, and Tubbataha Reefs in the Philippines, are largely funded by shark tourism. These activities can have demonstrable benefits, both in changing public perceptions for the better and incentivizing conservation initiatives. Unmanaged tourism, however, can quickly devolve into an additional burden on the focal species and their habitats. Going forward, if people are to benefit economically from threatened species, we need to ensure that the sharks and rays are benefiting too.

Right | Snorkelling with Southern Stingrays (*Hypanus americanus*)
Cayman Islands, Caribbean
Jason Washington | Ocean Image Bank

FURTHER READING

Sustaining marine wildlife tourism through linking limits of acceptable change and zoning in the wildlife tourism model. Bentz J, Lopes F, Calado H, Dearden P (2016) Marine Policy 68: 100–07.

Emerging challenges to shark-diving tourism. Gallagher AJ, Huveneers CP (2018) Marine Policy 96: 9-12.

Biological effects, conservation potential, and research priorities of shark diving tourism. Gallagher AJ, Vianna GM, Papastamatiou YP, Macdonald C, Guttridge TL, Hammerschlag N (2015) Biological Conservation 184: 365–79.

A global review of elasmobranch tourism activities, management and risk. Healy TJ, Hill NJ, Barnett A, Chin A (2020) Marine Policy 118: 103964.

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