Uttar Pradesh Journal of Zoology

Volume 45, Issue 22, Page 149-158, 2024; Article no.UPJOZ.4379
ISSN: 0256-971X (P)

Elasmobranch Conservation in India: Assessing Threats and Strategies for Sustainable Management

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Authors' contributions

This work was carried out in collaboration among all authors. Author KM planned and designed the review, managed a partial literature search, and wrote the first draft of the manuscript. Author SR finalized the entire draft along with rectifications, managed a partial literature search, and performed all sorts of correspondence. Author HLP managed the respective literature searches. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i224668

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4379

Review Article

Received: 30/09/2024
Accepted: 02/12/2024
Published: 07/12/2024

ABSTRACT

Elasmobranchs, a group that includes sharks, rays, and skates, play a crucial role in marine ecosystems as apex predators and benthic regulators. However, they face significant threats that jeopardize their populations and overall biodiversity. Major threats include overfishing, bycatch, habitat degradation, pollution, and climate change. Overfishing, driven by high demand for shark fins and ray gills, alongside unregulated fishing practices, has led to drastic declines in many species. Bycatch in commercial fisheries further exacerbates their vulnerability. Additionally, habitat destruction due to coastal development and pollution impacts their breeding and feeding grounds. Climate change contributes to shifts in ocean temperature and acidity, affecting elasmobranch

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Cite as: *Makwana, Ketan, H. L. Parmar, and Sivakumar Ragul. 2024. "Elasmobranch Conservation in India: Assessing Threats and Strategies for Sustainable Management". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (22):149-58. https://doi.org/10.56557/upjoz/2024/v45i224668.*

physiology and distribution. Effective conservation strategies are essential to address these threats and ensure the sustainability of elasmobranch populations. Key measures include implementing and enforcing sustainable fishing practices, creating marine protected areas, reducing bycatch through improved fishing gear, and enhancing global cooperation for conservation efforts. Addressing these threats requires a multifaceted approach involving scientists, policymakers, and local communities to safeguard the future of elasmobranch species and maintain the health of marine ecosystems.

Keywords: Sharks; IUCN; overfishing; conservation.

1. INTRODUCTION

“Elasmobranchs, like sharks, rays, and skates are cartilaginous fish that play a crucial role in marine ecosystems. As top predators, they help maintain a balanced food web by controlling prey populations. However, their slow reproduction rates and vulnerability to overfishing make them susceptible to population decline, which can have devastating effects on the entire ecosystem” (Stevens et al., 2000). The high international demand for shark fins is a primary driven of shark over-exploitation. This demand, primarily for use in shark fin soup, has led to unsustainable fishing practices that threaten shark populations worldwide (Clarke et al., 2007). Elasmobranchs also represent a significant part of India's marine fisheries industry, while often caught as bycatch they are sometimes directly targeted. Providing a valuable source of nutrition and income for individuals involved in artisanal, small-scale, and semi-industrial fishing (Akhilesh et al., 2023). Historically India has been one of the leading nations in elasmobranch fishing. Catching substantial quantities of sharks, rays, skates, and chimaeras, Chondrichthyans, like sharks and rays, are a valuable to many industries. They provide food (meat and shark fin soup), medicinal products (gills and shark liver oil), materials (leather and shark teeth), and even live specimens for aquariums. Recently, there has been growing interest in shark cartilage as a potential treatment for cancer and other ailments. Additionally, sharks and rays have become popular with scuba divers, attracting tourists to various locations around the world (Dent & Clarke, 2015). The proportion of elasmobranchs in India's annual marine fish landings has significantly declined over recent. In 1985, elasmobranchs accounted for 3.4% of the total landings, but, this figure dropped to less than 2% by 2005. and further declined to less than 1% by 2020. A particularly concerning period was between 1997 and 1998, when a peak in elasmobranch landings occurred. This was primarily due to increased fishing efforts, including targeting specific species like the whale shark, to meet the growing export demand for shark products. The intensification of fishing operations, such as the mechanization of boats and expanded offshore fishing, further contributed to this unsustainable trend (Kizhakudan, 2015).

Table 1. Morphological and characterization of Elasmobranchs (Thompson and Springer, 1965)

Elasmobranch	Character	Description
Sharks	Body shape:	Streamlined, torpedo-like.
	Movement:	Primarily swim with their tail.
	Feeding:	Predatory, consuming a variety of fish and marine life.
	Examples:	Great white shark, tiger shark, hammerhead shark.
Rays	Body shape:	Flattened, disc-like.
	Movement:	Propel themselves with their pectoral fins.
	Feeding:	Bottom-dwellers, often consume invertebrates.
	Examples:	Manta ray, stingray, eagle ray.
Skates	Body shape:	Similar to rays, but often smaller.
	Movement:	Propel themselves with their pectoral fins.
	Feeding:	Bottom-dwellers consume small fish and invertebrates.
	Reproduction:	Lay egg cases are known as "mermaid's purses."
	Examples:	Common skate, thornback skate, clearnose skate.

Fishery of Elasmobranch in India: According to ICAR-CMFRI estimates, annual elasmobranch landings in India have exhibited a fluctuating trend over the past several decades. While there was an overall decline from approximately 33,500 tons in 1961 to 25,900 tons in 2020, recent data for 2022 and 2023 indicate a slight uptick to 28,474 tons and 32,035 tons, respectively. While the Wildlife Protection Act (WPA) lists several elasmobranch species, they are not typically caught in large quantities as bycatch or targeted in fisheries. However, there was a notable incident in 2015-2016 when whale sharks were caught and utilized along the Andhra Pradesh coast. Following public outcry and awareness campaigns, this practice was stopped. Historically, sawfishes were considered a valuable fishery resource in certain regions of India, particularly in the northern Arabian Sea and the northern Bay of Bengal. However, their populations declined due to accidental capture in fishing gear and habitat destruction, leading to their near-disappearance from these areas (CMFRI, 2019).

Trade and Utilization: "Sharks and their products are in high demand both domestically and internationally. While demand for these products is not consistent across all regions of India, there is a strong market for shark meat, liver oil, jaw, and skin" (Karnad et al., 2020). In the past, international demand for shark fins and oil, as well as domestic demand for fresh and processed sharks, fueled targeted shark fisheries in certain areas. Recently, there has been a growing demand for the gill plates of manta and devil rays, despite international regulations to restrict their trade (Kizhakudan, 2015).

Threats to Elasmobranchs: Elasmobranchs, such as sharks, rays, and skates, are increasingly threatened by human activities, particularly in coastal areas. These threats are directly linked to the proximity of their habitats to human settlements and activities (Bornatowski et al., 2014). These threats are contributing to declining elasmobranch populations and putting many species at risk. Some of the emerging threats facing these marine creatures include:

Overfishing: "Overfishing, driven by the demand for shark fins, meat, and other products, is a major threat to elasmobranchs. They are often caught unintentionally in fishing gear like bottom trawls, longlines, and gillnets. Many elasmobranch species have slow growth rates and reproduce infrequently, making them especially susceptible to overfishing. It implies that populations of such species would take a long time to recover from the declined state" (Dulvy et al., 2021).

Bycatch: "Elasmobranchs are frequently caught unintentionally as bycatch in commercial fishing operations targeting other species. This can result in high mortality rates for elasmobranchs, particularly when they are discarded back into the ocean" (Gupta et al., 2020).

Habitat loss: "Habitat degradation and loss, primarily caused by coastal development, pollution, and climate change, are significantly impacting elasmobranch breeding and feeding grounds. Mangroves, estuaries, and coral reefs, which are vital habitats for many elasmobranch species, are particularly vulnerable to these threats" (Gallagher et al., 2012).

Climate change: "Climate change poses significant threats to elasmobranchs. Rising ocean temperatures can alter their distribution and affect the availability of their prey. Ocean acidification can harm their calcium-based skeletons and eggs while changing currents can disrupt their migration patterns" (Osgood et al., 2021).

Illegal Fishing: "Illegal, unreported, and unregulated (IUU) fishing practices often target elasmobranchs for their valuable fins and meat. These activities can undermine conservation efforts and further contribute to population declines" (Cruz et al., 2021).

Trade and shark finning: "The global trade in shark fins, primarily for shark fin soup and traditional medicines, is a major driver of elasmobranch exploitation. Shark finning, a cruel and wasteful practice that involves removing fins from sharks and discarding the rest of the body at sea, is a significant contributor to this problem" (Verlecar et al., 2007).

Shark mislabeling: "Shark mislabeling is a deceptive practice where shark species are misidentified or misrepresented in the seafood supply chain. This can happen at any stage, from fishing to distribution. Mislabeling shark products can have negative consequences for both consumers and the marine environment" (Bornatowski et al., 2013).

Pollution: "Pollution from plastic debris, chemical pollutants, and heavy metals can harm elasmobranchs in various ways. These contaminants can directly affect elasmobranchs or indirectly by contaminating their prey and habitats" (Tiktak et al., 2020).

2. MANAGEMENT AND CONSERVATION STRATEGIES OF ELASMOBRANCHS IN INDIA

Research and monitoring: "The main government-funded agencies conducting elasmobranch research in India are the Fishery Survey of India (FSI) and the ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI). FSI estimates fish abundance through experimental fishery surveys, while ICAR-CMFRI estimates stock status using fishery landing data collected through a statistically designed sampling method" (Mukesh et al., 2019). "Despite having good knowledge of the spatial distribution of elasmobranch species in India, information on species-specific stock status, critical habitats, conservation, management, socio-economics, and human dimensions of elasmobranch fisheries is limited or absent" (Gupta et al., 2022). "The State Fisheries Departments (SFDs) have the flexibility to create and implement their own conservation rules and regulations, such as zoning, closed areas, minimum legal size (MLS), and conservation incentives. These regulations are implemented within the framework of the Marine Fishing Regulating Acts (MFRAs), which are often general and do not address specific species needs. Therefore, the SFDs play a crucial role in enforcing conservation and management measures. Government agencies, such as the Coastal/Marine Police, Central Board of Excise and Customs, Indian Coastguard, Wildlife Crime Control Bureau, Indian Navy, and the Directorate of Revenue Intelligence, also contribute to monitoring and controlling fishing and trading of protected and regulated species" (Akhilesh et al., 2023; Williamson et al., 2019).

National Legislation for Elasmobranch Conservation in India: "The Wildlife Protection Act (WPA) is the primary national legislation that directly addresses the conservation of flora and fauna in India. It is administered by the Ministry of Environment, Forest, and Climate Change (MoEF&CC) and aims to identify and classify high-risk species or groups and regions with rich biodiversity or habitats of threatened fauna that require prioritized conservation and protection" (Vivekanandan and Zala, 1994; Haque et al., 2019). "The WPA categorizes wildlife requiring conservation measures into various schedules (I, II, III, IV) with varying protection levels and penalties. Habitats are protected through declared Protected Areas (PAs) on land or sea, including Wildlife Sanctuaries, National Parks, Community Reserves, and Conservation Reserves. Additionally, coastal areas are protected under the Environment (Protection) Act, 1986, with declared coastal regulation zones and formulated rules" (Pravin, 2000). "The WPA was initially enacted for terrestrial biodiversity conservation. It was expanded to include mammals and reptiles in 1972, birds in 1991, and fishes in 2001 due to concerns over the mass exploitation of whale sharks in the northern Arabian Sea. This led to the inclusion of whale sharks and all 'Shark and Ray' species under the WPA in 2001" (Akhilesh et al., 2014).

IUCN Status of Elasmobranch in India: "India's coastal waters are home to an impressive array of elasmobranchs, with around 175 species recorded across 44 families. Among the documented species, 168 have been evaluated for their extinction risk by the IUCN Red List of Threatened Species. The findings are concerning: 15% are classified as Critically Endangered, indicating an imminent risk of extinction. Furthermore, 24% are categorized as Endangered, while 28% are considered Vulnerable. These statistics emphasize the urgent need to develop effective fisheries management and conservation strategies to safeguard the diverse elasmobranch species in India's marine environment" (Akhilesh et al., 2020; Bineesh et al., 2023; Akhilesh et al., 2023).

Regional and international commitments: "At both regional and international levels, India has actively engaged in numerous conventions and commissions dedicated to the conservation of elasmobranchs. One of the earliest global initiatives was the United Nations International Plan of Action for Sharks (UN-IPOA) established in 1999. This voluntary plan requires each country to develop and implement its own National Plan of Action (NPOA) for shark management and conservation" (Walker, 2010). In 2015, the ICAR-CMFRI published guidelines on the NPOA for Sharks in India, identifying research and policy gaps and outlining priorities for action. A draft NPOA-Shark for India has also been developed by the Bay of Bengal Programme Intergovernmental Organisation (BoBPIGO). Additionally, India is a signatory to several key agreements including CITES, CMS, the Indian Ocean Tuna Commission (IOTC), the Convention on Biological Diversity (CBD), and the Sustainable Development Goals (SDGs). These commitments involve implementing various provisions, with CITES, CMS, and IOTC agreements being legally binding (Kizhakudan, 2015).

Table 2. Existing national and state regulations and compliance level

Policy	Current authority	Current implementing agency	Compliance level	Duration
Management of fisheries in coastal waters within 12 nm	State Government	State Fisheries Department	Limited	Throughout the year, Marine Fishing Regulation Acts (MFRAs)
Closed season in territorial waters	State Government	State Fisheries Department	Good	Once every year, 61 days (15 April to 14 June along the east coast, and 1 June to 31 July along the west coast
Fisheries spatial zones for artisanal fisheries in territorial waters	State Government	State Fisheries Department	Limited	Throughout the year, MFRA
Fishing efforts in exclusive economic zone (EEZ)/fishing boat license and registration	State Government	State Fisheries Department	Limited	Throughout the year
Closed season in EEZ beyond 12 nm	Central Government	Coast Guard, in coordination with state governments	Excellent	Once in a year, 45 days
Wildlife Protection Act (WPA)	Central Government	State Forest Departments, WCCB	Limited	Throughout the year
Minimum legal size	State Government	Fisheries Department	Good	Throughout the year
Mesh size	State Government	Fisheries Department	Limited	Throughout the year
Marine protected areas	Central Government	State Forest Departments	Good	Throughout the year
Awareness	Open	Open	Limited	
Fin attached policy	Central Government	State Forest Departments, WCCB	Excellent	Throughout the year
Blanket ban on shark fin export	Central Government, Ministry of Commerce	Customs, Coastguard, Navy, other security/screening agencies	Good	Throughout the year
Conservation incentives for release of marine WPA species	Maharashtra, Gujarat (restricted to whale shark)	State Forest Department	Good	Throughout the year
Marine protected area	State Government/ Central Government	State Forest Departments	Good	Throughout the year

Table 3. Elasmobranch species Listed on CITES, CMS, and their IUCN Status (https://vindhyabachao.org/wildlife_guidelines/schedule_species_fishes.pdf)

Common name	Scientific name	CITES	CMS	IUCN status
Sharks				
Pelagic Thresher	*Alopias pelagicus*	App II (2016)	II (2014)	Endangered (EN)
Bigeye Thresher	*Alopias superciliosus*	App II (2016)	II (2014)	Vulnerable (VU)
Common Thresher	*Alopias vulpinus*	App II (2016)	II (2014)	Vulnerable (VU)
Great White Shark	*Carcharodon carcharias*	App II (2004)	I and II (2002)	Vulnerable (VU)
Silky Shark	*Carcharhinus falciformis*	App II (2016)	II (2014)	Vulnerable (VU)
Oceanic Whitetip Shark	*Carcharhinus longimanus*	App II (2013)	Not listed	Critically Endangered (CR)
Basking Shark	*Cetorhinus maximus*	App II (2001)	I and II (2005)	Endangered (EN)
Shortfin Mako	*Isurus oxyrinchus*	Not listed	II (2008)	Endangered (EN)
Longfin Mako	*Isurus paucus*	Not listed	II (2008)	Endangered (EN)
Porbeagle Shark	*Lamna nasus*	App II (2013)	II (2008)	Vulnerable (VU)
Scalloped Hammerhead	*Sphyrna lewini*	App II (2013)	II (2014)	Critically Endangered (CR)
Great Hammerhead	*Sphyrna mokarran*	App II (2013)	II (2014)	Critically Endangered (CR)
Smooth Hammerhead	*Sphyrna zygaena*	App II (2013)	Not listed	Vulnerable (VU)
Whale Shark	*Rhincodon typus*	App II (2001)	II (1999)	Endangered (EN)
Spiny Dogfish	*Squalus acanthias*	Not listed	II (2008)	Vulnerable (VU)
Rays				
Narrow Sawfish	*Anoxypristis cuspidata*	App I (2007)	I and II (2014)	Critically Endangered (CR)
Dwarf Sawfish	*Pristis clavata*	App I (2007)	I and II (2014)	Critically Endangered (CR)
Smalltooth Sawfish	*Pristis pectinata*	App I (2007)	I and II (2014)	Critically Endangered (CR)
Largetooth Sawfish	*Pristis pristis*	App I (2007)	I and II (2014)	Critically Endangered (CR)
Green Sawfish	*Pristis zijsron*	App I (2007)	I and II (2014)	Critically Endangered (CR)
Reef Manta Ray	*Mobula alfredi*	App II (2013)	I and II (2014)	Vulnerable (VU)
Giant Manta Ray	*Mobula birostris*	App II (2013)	I and II (2011)	Endangered (EN)
Longhorned Pygmy Devil Ray	*Mobula eregoodootenkee*	App II (2016)	I and II (2014)	Endangered (EN)
Atlantic Devil Ray	*Mobula hypostoma*	App II (2016)	I and II (2014)	Endangered (EN)
Spinetail Devil Ray	*Mobula japonica*	App II (2016)	I and II (2014)	Near Threatened (NT)
Shortfin Devil Ray	*Mobula kuhlii*	App II (2016)	I and II (2014)	Endangered (EN)
Giant Devil Ray	*Mobula mobular*	App II (2016)	I and II (2014)	Endangered (EN)

Common name	Scientific name	CITES	CMS	IUCN status
Pygmy Devil Ray	*Mobula munkiana*	App II (2016)	I and II (2014)	Vulnerable (VU)
Sicklefin Devil Ray	*Mobula tarapacana*	App II (2016)	I and II (2014)	Endangered (EN)
Bentfin Devil	*Mobula thurstoni*	App II (2016)	Ray I and II (2014)	Endangered (EN)
Lesser Guinean Devil Ray	*Mobula rochebrunei*	App II (2016)	I and II (2014)	Vulnerable (VU)

Fishbase: https://www.fishbase.de/summary/Mobula-rochebrunei.html)
CMS: Convention on the Conservation of Migratory Species of Wild Animals
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
IUCN: International Union for Conservation of Nature

State laws (Marine Fishery Regulation Acts): Marine fisheries management in India is a collaborative effort between the Government of India (GoI) and the state governments of nine coastal states, as well as four Union Territories (UTs). The states and UTs oversee fisheries within the territorial sea, while the GoI manages those beyond 12 nautical miles in the Exclusive Economic Zone (EEZ). This arrangement is supported by the National Policy on Marine Fisheries (NPMF, 2017) and guided by Article 21 of the Indian Constitution. States regulate their marine fisheries through Marine Fisheries Regulations Acts (MFRAs), which include operational guidelines for fishing. These guidelines cover aspects such as fishing areas based on gear types, mesh size regulations, and seasonal fishing bans (see Table 2) (Parappurathu & Ramachandran, 2017).

Protected Areas in Elasmobranch Conservation: Marine reserves are particularly effective for safeguarding species with limited geographical ranges, such as those found in coral reefs or temperate reef systems. In these environments, eggs and larvae can be carried by ocean currents from the reserve to other areas, benefiting both the protected zones and the areas where fishing occurs. Closed areas have been established to safeguard specific segments of elasmobranch populations that are particularly susceptible to fishing or other human disturbances. One of the earliest examples of this approach is the protection of the tope shark (school shark), *Galeorhinus galeus* (Fowler et al., 2002).

3. CHALLENGES FOR CONSERVATION OF ELASMOBRANCHS IN INDIA

i. **Species diversity and taxonomic gaps:** "Genetic population structure studies are crucial for understanding population boundaries and subpopulation dynamics, which are key to develop effective management strategies. Recent research using mitochondrial markers on the scalloped hammerhead shark (*Sphyrna lewini*) (Sukumaran et al., 2020) and the oceanic white tip shark (*Carcharhinus longimanus*) has shown that these species have panmictic populations with little significant genetic differentiation in Indian waters. These findings suggest that both species should be managed as a single stock in the region, which indicates the need for coordinated management efforts to enhance the regional conservation outcomes" (Sreelekshmi et al., 2020).

ii. **Limited information on stock and migration:** "Analysis of population structure through genetic studies or morphometrics reveals crucial information about population boundaries and subpopulation organization, which is essential for creating effective management strategies. Research on the genetic variation of shark population using mitochondrial markers has highlighted significant gene flow, connectivity, and existence of local barriers for mixing of different population groups" (Sreelekshmi et al., 2020).

iii. **Bycatch Reduction**: "Most landed elasmobranchs are bycatch from fishing gears such as trawl nets, pelagic longlines, and gillnets. Due to their value, mitigating actions to reduce bycatch often face resistance and present challenges for implementation. In coastal states like Gujarat and Maharashtra, there is a practice of on-board release of sharks, with monetary incentives provided to encourage live release" (Gupta et al., 2020). "Additionally, the use of bycatch reduction techniques, such as mesh-size regulation in trawl nets and bycatch reduction devices, is still limited and needs to be expanded. In 2018, a joint study by ICAR-CIFT, ICAR-CMFRI, and WWF-India was launched to address shark bycatch and improve the management of shark resources in Gujarat" (CMFRI, 2019).

4. CONCLUSION

Elasmobranchs (sharks, skates, and rays) are crucial to the health of marine ecosystems, but their populations are declining due to overfishing, bycatch, habitat loss, and other threats. India has historically been a major elasmobranch fishing nation, but landings have decreased in recent years. However, some populations remain threatened, particularly sawfishes. There are a number of national and state regulations in place to conserve elasmobranchs, but enforcement can be limited. India is a signatory to several international agreements on elasmobranch conservation. More research is needed to improve the management of elasmobranch fisheries in India.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/4379