CHAPTER 1
INTRODUCTION

Elasmobranchii is a highly ancient group of vertebrates that has managed to exist for over 400 million years, starting with the Devonian period. It is the second largest class of fishes, following Osteichthyes. They are marine vertebrates characterized by a cartilaginous endoskeleton, distinguishing them from Osteichthyes (bony fishes) which have true bones. This group encompasses super-order Selachii (sharks) and super-order Batoidea (rays and skates). Elasmobranchs possess placoid scales, which are different from the scales of bony fishes, and their internal skeletons are formed of calcified cartilage (Last and Stevens, 2009). The body forms of Elasmobranchii share many similar characteristics but vary significantly between orders, reflecting adaptations to their lifestyle, habitat, and environment (Compagno, 1999). Although they have a similar outward appearance to genuine fishes, their structure is so different that they are classified in a separate class (Jordon, 1905). Elasmobranch communities consist of several species such as sharks, rays, skates, and saws. These species belong to the class Elasmobranchii, which was previously classified as a sub-class within the class Chondrichthyes (Tricas, 1997). The term 'Elasmobranch' is a combination of the Greek word 'elasmo' meaning 'metal plate' and the Latin word 'branchus' meaning 'gill', as stated by the World Register of Marine Species (WoRMS).

Class Elasmobranchii are mainly characterised by (i) They do not have a swim bladder and instead rely on a large oily liver to control their buoyancy. (ii) They have five to seven pairs of gill cleft apertures that are arranged independently and tangentially. (iii) They have inflexible dorsal fins. (iv) They have claspers, which are used for visual identification of their sex, sex dimorphism. (v) They have a cartilaginous endoskeleton. (vi) They have dermal denticles. (vii) They have multiple rows of teeth. (viii) Their upper jaw is not connected to the cranium (skull). (ix) Deep ocean species in particular have a high accumulation of ammonia in their bodies (Tricas, 1997).

Elasmobranch are characterized by polyploidy and a high degree of heterogeneity in terms of marine animal breeding (Martin, 2001). Hybridization is typically conducted in a controlled setting, which poses a constraint for numerous research organizations worldwide. The current elasmobranch populations exhibit various jaw adaptations, including amphistyly, orbitostyly, hyostyly, and euhyostyly.

In amphistyly, the palatoquadrate bone is connected to the chondrocranium through a postorbital articulation, with ligaments mostly supporting it in the anterior direction. The hyoid bone is positioned posteriorly to the mandibular arch, however it provides limited support to the upper and lower jaws. In orbitostyly (Squalea except for Hexanchiformes), the connection between the orbital wall and the hyoid bone is responsible for most of the support. Hyostyly (e.g., *Carcharodon carcharias*), in contrast, refers to the connection between the upper jaw and the skull through the ethmoid bone. The hyoid bone is expected to provide significantly greater support to the jaw compared to the ligaments in the front. Euhyostyly (Batoids), also referred to as real hyostyly, is characterized by the absence of a ligamentous attachment between the mandibular cartilages and the cranium. Instead, the hyomandibular cartilages are the sole way of supporting the jaw, whereas the ceratohyal and basihyal elements connect with the lower jaw but are not attached to the remainder of the hyoid (Wilga, 2005, 2008; Wilga et al., 2007).

The global elasmobranch fauna has over 1426 species, (Fricke et al., 2023). New species continue to be discovered and published each year. Elasmobranchs are distributed widely over various aquatic environments, including freshwater lakes, rivers, estuaries, coastal waters, reefs, open-ocean, and the deep-sea. Several elasmobranchs' species, such as the blue shark (*Prionace glauca*), Whale shark (*Rhincodon typus*), Pelagic stingray (*Pteroplatytrygon violacea*), and Tiger shark (*Galeocerdo cuvier*), have a worldwide distribution and can be found in various parts of the world's oceans. Several species are restricted to specific places, where they are geographically isolated or endemic to certain localities. Examples include the Pyjama shark (*Poroderma africanum*), the Maltese skate (*Leucoraja melitensis*), the Yellownose skate (*Dipturus chilensis*), and the Gummy shark (*Mustelus lenticulatus*).

Elasmobranchs are extremely vulnerable to excessive exploitation. Organisms with complex life history traits, such as slow development, extended lifespan, delayed sexual maturity, and poor reproductive capacity, are collectively referred to as having K-selected life history strategies. These qualities make them vulnerable to the impacts of fishing (Stevens et al., 2000). The life history and biology of elasmobranchs are not well understood, and this lack of understanding has made it challenging to assess their vulnerability to exploitation and has hindered efforts to develop conservation and

management strategies (Frisk et al., 2001). Some elasmobranch species display spatial heterogeneity in their life cycle traits and may respond differently to exploitation, as indicated by Kuparinen and Merila (2007). Therefore, it is necessary to develop management plans that are appropriate to each location. The intensified selective fishing for elasmobranchs and the substantial incidental catch in the commercial fisheries have raised global concerns for the long-term viability of this group.

1.1 Ecological significance of Elasmobranch

Elasmobranch fish serve as an indicator of the coral reef ecology. The elasmobranch populations can be found in a wide range of depths, from the intertidal zone to the deepest parts of the ocean. The Elasmobranch communities, which consist of cartilaginous species, are divided by their habitat into different groups. These groups include species found on the continental shelves, which range from the intertidal zone to a depth of about 200 meters. There are also species found on the continental slopes, which are located below 200 meters and extend to the ocean floor. Finally, there are species found in the oceanic zone, which is beyond the continental shelves and slopes, and includes the area above the sea bottom. This classification was described by Compagno et al. (2005). The population of elasmobranch in coral reefs has been greatly altered due to fishing pressure and other human-induced influences (Lobo et al., 2008). Comprehending these trophic interactions, the placement of species within a food web is a crucial factor in elucidating the dynamics of marine ecosystems and the effects that individual species have on the divisions within the trophic network. Failure to recognize the importance of both direct and indirect effects can lead to significant gaps in our understanding of the causes and consequences of conflict in food webs. Modifications to one or more elements in a food web can have far-reaching consequences, causing shifts in the population size and interconnections of other species.

The population oscillation of meso predators in a trophic flow is determined by the relative abundance of prey populations, which is influenced by both the absence of direct predation and the indirect impacts such as perceived competition, exclusion competition, and behavioural effects. This course of action will occur when there is a decrease in the population of large predators, resulting in an increase in the population of transitional components, which in turn leads to a fall in the population of the prey of

meso predators. (Heithaus and Vaudo, 2004). There have been few comprehensive studies conducted on tropical trophic networks. On the other hand, the increase of meso predator populations has mostly been observed in cold and temperate seas or in habitats with minimal biodiversity. Contemporary studies suggest that Elasmobranch communities, which include sharks, rays, skates, and related species, play a crucial role in their respective food chains. The decline in the population of large sharks can have significant impacts on the flow of energy through the food chain, mostly through top-down effects (Last, 2007). However, the management of lower levels of a food chain's residents is not always directly linked to the predation of one or more distinct prey species. The shark and its relatives are the most extensive and diverse predators in the Elasmobranch community. They serve as a model for enhancing the understanding of predatory responsibility. The entire shark community is typically regarded as apex predators. The majority of shark species were Bull shark, Copper shark, Caribbean reef shark, Great white shark, Tiger shark, and others. Recently, there has been an increased understanding of the important role that apex predators play in ecosystem functioning. This, along with growing conservation concerns for commercially harvested species, has led to a significant increase in research on Elasmobranch communities (Last, 2007). Continual investigation in this field has led to the publication of numerous phylogenies at frequent intervals, however a conclusive answer has not been achieved (Lopez et al., 2006).

1.2 Molecular Aspects of Elasmobranchs

Elasmobranch are a varied taxonomic group, and its systematic ordering and phylogeny are largely uncertain. Almost three decades ago, Avise and Ellis (1986) highlighted mitochondrial DNA (mtDNA) genes as crucial markers in phylogeographic research. Recent molecular studies indicate that Batoids (skates and rays) are not derived from Selachians (sharks) but form a monophyletic superorder within Elasmobranchii, sharing a common ancestor with Selachians (Douady et al., 2003; Winchell et al., 2004). This finding contrasts with earlier taxonomic views by Bigelow and Shroeder (1948), who proposed significant divisions between batoids and sharks. Research by Compagno (1977) suggests that Batoids, such as saw sharks and angel sharks, are descended from sharks. The phylogeny of elasmobranch communities has been a subject of extensive debate due to their crucial role as a basal position in the

vertebrate tree. Winchell et al. (2004) identified four main issues related to anatomical cladistics in Elasmobranch communities. Firstly, the cartilaginous endoskeletons are poorly preserved. Secondly, the musculoskeletal system of the closest extant out group, the Chimeras, exhibits divergent features. Thirdly, there is a high likelihood of convergent evolution due to similar ecological niches. Lastly, the conservation of shark morphology and the absence of recognizable 3 synapomorphies pose challenges. Various phylogenies have been proposed for elasmobranch populations due to a combination of morphological and molecular evidence, as indicated by Douady et al. (2003) and Winchell et al. (2004).

Despite attempts to resolve the taxonomic confusion in elasmobranch communities, the data collected has rarely been utilized to determine the relationships between species within an evolutionary framework or phylogenetic (Beheregaray, 2008). Furthermore, there is a significant absence of research that use molecular methodologies to examine these animal populations. Most molecular phylogenetic studies of elasmobranch communities focus on higher taxonomic levels and primarily aim to determine the evolutionary placement and origin of the study species (Douady et al., 2003; Winchell et al., 2004; Iglesias et al., 2005). The classification of Elasmobranch communities is a topic of ongoing debate. However, in general, these communities can be divided into three groups: Squalomorphs, Galeomorphs, and Squatinomorphs. The Squalomorph group consists of approximately 30 families and 368 species. The Galeomorph group includes about 470 species from 21 families, which are part of the Batoid group (Compagno, 1977, 1984; Gold and Springer, 1989).

1.3 You Only Look Once (YOLO): An object detection (Deep learning) approach to Elasmobranchs

The taxonomy of fish species is a crucial aspect of managing fisheries and monitoring the environment. Precise and dependable species identification of fish is essential for identifying endangered species, determining the ideal harvest size or timing, monitoring ecosystems, and developing an intelligent production management system (Chang et al., 2005; Cabreira et al., 2009). Accurate identification of fish species is crucial, particularly when their survival is at risk or in danger, due to regulatory restrictions on fishing methods. The majority of fisheries employ the conventional

method of species identification, which requires significant human effort, takes up time, and has the potential to impact the natural behaviour of the fish.

Object recognition and tracking are crucial in various practical contexts, including monitoring (Raghunandan et al., 2018), assisting individuals with physical impairments (Dionisi et al., 2012), examining microscopic objects (Wang et al., 2019), and analysing marine species (Xu et al., 2019). Extensive monitoring of marine species has been conducted during the past decade. Nevertheless, the analytical tasks that are linked to this still mainly depend on biologists, which has the potential to introduce errors due to the manual nature of the procedure. By implementing automated detection and tracking systems, the errors can be mitigated through minimizing human involvement with the environment and offering a supplementary tool for biologists to assess various applications (Baldaniya and Mankodi, 2024). Significant progress has been made in machine learning, particularly in the field of deep learning utilizing convolutional neural networks (CNN). These advancements have shown superior performance in accuracy and speed metrics compared to standard machine learning approaches, specifically in the area of object detection (O'Mahony et al., 2020; Redmon et al., 2016; Redmon et al., 2018; Uemura et al., 2020). These enhancements render such algorithms advantageous for utilization in practical scenarios. Automated detection and tracking of marine species are crucial for monitoring the population status of endangered and threatened species in the aquatic ecosystem. A technique utilizing region segmentation was introduced in (Maire et al., 2015), which incorporated deep Convolutional Neural Networks (CNNs) to enhance the recall and precision measures in the detection of marine organism. The methodology was evaluated using a dataset of aerial photos obtained from animal surveys. A study was proposed in (Xu et al., 2019) that utilized advanced computer vision techniques along with deep CNN models to recognize and classify several species of fish.

The YOLO methodology was employed to identify and monitor aquatic organisms, such as sharks. The approach yielded satisfactory outcomes during its evaluation on deep-sea videos. A refined iteration of the YOLO technique was introduced to identify fish and sharks, surpassing the normal YOLO method in terms of precision score performance (Raza et al., 2020). Moreover, the utilization of ResNet-50, a convolutional neural network consisting of 50 layers, provides substantial benefits

in image analysis due to its capacity to acquire intricate feature representations for various types of images. Accurate precision is crucial for comprehending the distribution of species, the sizes of populations, and the diversity of life, all of which are necessary for implementing effective policies for management and conservation.

Combining YOLO and ResNet-50 for the task of elasmobranch species identification from images and videos can revolutionize the way data were collected and analysed in marine biodiversity studies (González-Sabbagh and Robles-Kelly, 2023). It offers a fast, accurate, and efficient method for real-time identification, which is paramount in addressing the challenges of marine conservation and contributing to the sustainable management of these vulnerable marine resources (Davis, 2022).

1.4 Global Elasmobranch Fishery

Elasmobranch have served as a significant source of food for countless years and have been utilized by Persians and Cretans in coastal areas for more than 5000 years (Vannuccini, 1999). Currently, they hold significance as both food and processed/pharmaceutical items. Sharks hold greater significance than skates, rays, and chimaeras in the specific elasmobranch fishery. The earliest recorded instance of targeted fishing for elasmobranchs in the world can be traced back to the 18th century. In the 1770s, harpoon fishing for Basking sharks (*Cetorhinus maximus*) began off the western coast of Ireland (Fowler, 1996). Additionally, the exploitation of spiny dogfish (*Squalus acanthias*) for liver oil has been documented since the 1870s (McFarlane and Beamish, 1987).

The commercial exploitation of elasmobranch, specifically aimed for their food and leather industry, began following the end of the First World War (Vannuccini, 1999). The fishing industry has had consistent growth since the 1920s, resulting in a detrimental effect on fish stocks (Walker, 1998). The identification and popularity of elasmobranch livers as a rich source of Vitamin A led to a surge in their exploitation during the 1940s (Kroese and Sauer, 1998; Vannuccini, 1999; Stevens et al., 2000). Elasmobranchs are targeted for commercial, artisanal, and recreational fishing, although a significant proportion are also unintentionally caught as bycatch in commercial fisheries. The substantial rise in chondrichthyan fisheries and commerce can be attributed to the high demand for shark fins, meat, and cartilage. This demand

has also led to deliberate and illicit fishing practices, including unreported and unregulated (IUU) fishing for sharks.

There is a growing global concerned about the excessive exploitation of top predators in the ocean, mostly due to their specific life cycle features that make them vulnerable to overfishing (Smith et al., 1998). Excessive exploitation and the degradation of habitats may have adverse effects on stocks (Musick, et al., 2000; Stevens, 2000; Musick and Ellis, 2005).

The true extent of the impacts of fishing and habitat degradation on exploited elasmobranch groups will go undiscovered until there is a significant and observable decrease in the catch of the species targeted or caught incidentally. The majority of elasmobranch fisheries that are specifically targeted are commonly referred to be boom and bust fisheries since they have a short lifespan. Reports of declining elasmobranch stocks due to fishing and bycatch are observed worldwide. Examples include the Californian soup fin shark in the *Galeorhinus galeus* fishery (Ripley, 1946), the Irish Sea skate in the *Dipturus batis* fishery (Brander, 1981), the basking shark (*Cetorhinus maximus*), and the spiny dogfish in the *Squalus acanthias* fishery (Holden, 1974). The fishery for Oceanic whitetip (*Carcharhinus longimanus*) and Silky shark (*Carcharhinus falciformes*) had a reduction between 1950 and the late 1990s in the Gulf of Mexico (Baum and Myers, 2004) and the shark population in the northwest Atlantic Ocean (Baum et al., 2003) also decreased during this time period.

The worldwide capture of elasmobranch species, as reported by the Food and Agricultural Organization (FAO), has shown a significant increase over time. In 1950, the catch was 271,800 tonnes, which rose to 822,000 tonnes in 1999 (Vannuccini, 1999). Since 1985, the catch has been steadily increasing at an average annual rate of 2% (Stevens et al., 2000). Nevertheless, it constitutes merely 1% of the global annual marine fish catch (Walker, 1998). It is well acknowledged that the elasmobranch catches information reported are likely to underestimate the actual fisheries landings. The majority of the data on elasmobranch catch does not account for the significant amounts caught unintentionally as bycatch. According to Bonfil (1994), bycatch alone accounts for 50% of the total catch of chondrichthyan species. Inadequate surveillance and estimation of catches in coastal nations result in imprecise catch statistics, which obstructs the implementation of effective management strategies.

The targeted fishing of elasmobranch is practiced in 26 countries, with Indonesia, India, Spain, Taiwan, Portugal, and Japan being the main countries involved. The top 20 fishing nations are responsible for 80% of the global elasmobranch catch (Lack and Sant, 2011). According to the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN), about 30% of all sharks are at risk of extinction or are very close to being at risk (Dulvy et al., 2014). In response to the decline of multiple elasmobranch fisheries and the recognition of the crucial role of elasmobranchs in the ecosystem, the Food and Agricultural Organisation (FAO) approved and implemented the International Plan of Action (IPOA) for the Conservation and Management of Sharks (including all elasmobranchs) in 1999. This plan, operating under the Code of Conduct for Responsible Fisheries (CCRF), encourages the voluntary management of fisheries through the establishment of national shark plans and collaboration among regional fishing nations to ensure the long-term viability of shark populations. The Convention on International Trade in Endangered Species (CITES) oversees the global trade of elasmobranchs and regulates the trading of endangered and protected species listed in CITES Appendix.

1.5 India's elasmobranch fishery

India – a mega biodiversity nation is an integral and the largest part of the central Indian Ocean region along with other countries Bangladesh, Indonesia, Maldives, Malaysia, Myanmar, Thailand and Sri Lanka (Gopi and Mishra, 2015). India with a coastline of about 8129 km length and 2.02 million sq. km area of the exclusive economic zone (EEZ). Indian coastline interacts with nine states and four union territories. Indian coastline is formed as a result of continental drift of Gondwana land. The mainland coastline is divided into two parts - Eastern coastline and Western coastline. Indian fisheries have a long history, starting with Kautilya's Arthasastra describing fish as a source for consumption and provide evidence that fishery was a well-established industry in India and fish was relished as an article of diet as early as 300 B.C (Joshi et al., 2017).

India is the third largest fish producing country (CMFRI, 2023), contributing 8% to the global fish production and rank second in aquaculture production (Ministry of fisheries Government of India, 2021-2022). The fisheries industry plays a crucial role in the socioeconomic advancement of the nation. This has been recognized as a

powerful catalyst for generating income and promoting the growth of several additional industries. It also serves as a source of affordable and healthy food, while contributing to foreign trade earnings. Primarily, it serves as the primary means of sustenance for a significant portion of financially disadvantaged residents in the region.

According to the Food and Agriculture Organization (FAO, 2009) and Permana et al. (2021), India is the second most significant country in terms of fishing for elasmobranchs, after Indonesia. The fisheries resources of elasmobranchs, which include sharks, rays, and skates, are harvested using various fishing equipment such as longlines, trawl nets, drift gillnets, and hooks and lines in the Indian Exclusive Economic Zone (EEZ). India has a rich history of fishery, with one of the earliest documented instances of elasmobranch fisheries being reported by Day (1863) from the Kerala coast, India. Prior to 1980, elasmobranchs were sporadically captured by various traditional vessels and gear in India, and they were solely regarded as incidental catch. Elasmobranch fishing in Indian waters has been specifically focused on using gill nets, hooks and lines, and long lines since 1990 (Bonfil, 1994; Hanfee, 1996, 1999). Currently, there is a widespread practice of conducting multiday remote water fishing targeting elasmobranchs throughout the Indian Exclusive Economic Zone (EEZ). During 2022 the estimated all India elasmobranch landing was 28474 tonnes (sharks 43%, rays 48% and skates 9% and Chimaeras 0.2%), of which major contributions were from states like Tamil Nadu, Kerala and Gujarat (Fig. 1.1) (CMFRI, 2022).

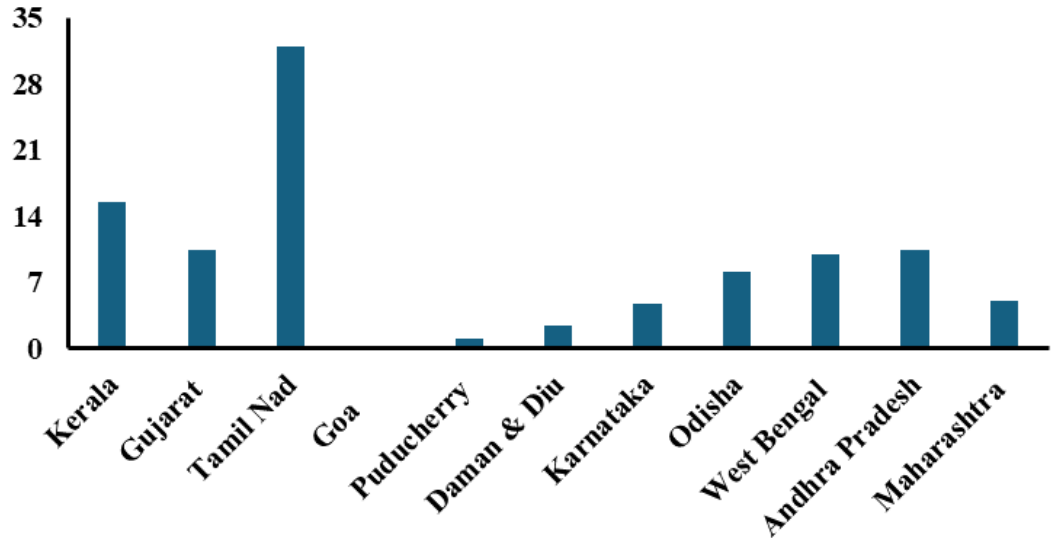

Figure 1.1: State-wise contribution to all-India Elasmobranch landings in 2022

The commercial elasmobranch fishery of India has undergone several changes during the last decades. The (Fig. 1.2) illustrates the trends in catch numbers for sharks, skates, and rays from 2011 to 2022. The overall trend of sharks shows a decrease in catch, starting from 26,746 in 2011 to 12,296 in 2022, with some fluctuations in between. In Skates trend is more variable, but there is no clear long-term increase or decrease the numbers fluctuate significantly, with peaks and troughs throughout the years. Rays catch trend shows an initial increase from 24017 in 2011 to a peak of 27,802 in 2012, followed by a general decrease to 13,646 in 2022.

The Rio Convention on Biodiversity, which took place in December 1992 in Brazil, highlighted the importance of conserving and responsibly utilizing biodiversity. In India, it is crucial to assess the status of exploited elasmobranchs in order to ensure their sustainable exploitation and develop effective management plans, given the presence of multispecies and multi-gear fisheries. Developing an elasmobranch management plan requires fundamental information on the fauna, including their diversity, distribution, habitat, capture statistics, and biological characteristics. This information is vital for the formulation of the plan.

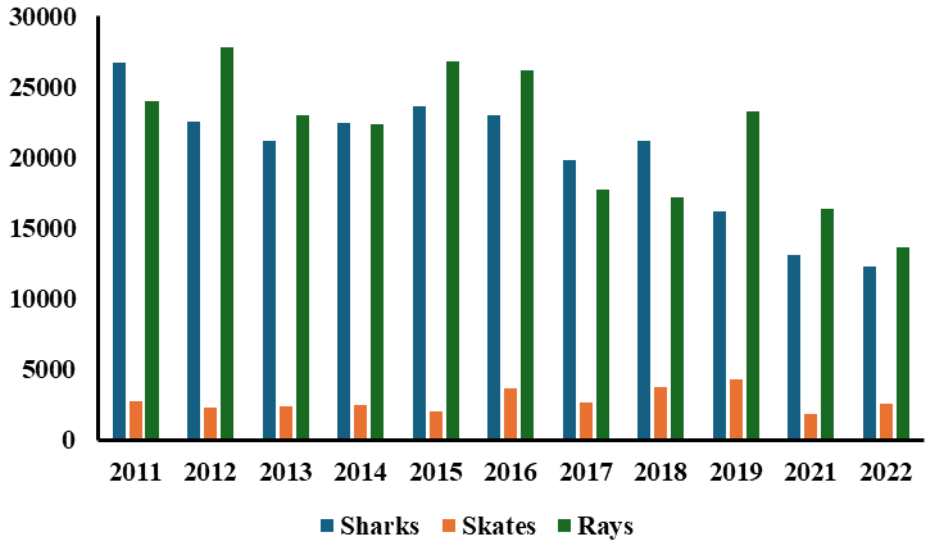

Figure 1.2: Elasmobranch fish landing(tonnes) in India year 2011-2022 (Source: CMFRI, 2022)

The Gujarat maritime zone is located in the Northwest coast of India under the FAO fishing Subarea 51.4, Eastern Arabian Sea (FAO, 2024). The Gujarat state's coastal area is very different in terms of geomorphology from the rest of the West coast of India. The coastal zone of Gujarat state is divided into three major geographical parts, two major gulfs; namely the Gulf of Kachchh and the Gulf of Khambhat, and the Saurashtra coastline, each of which has its distinctive character, climate variation, and diverse geo-environmental features, which embrace diverse coastal habitats as well as ecological significant biota. In Gujarat, the fishing sector's catch distribution by boat type is distinctly skewed towards mechanized boats, which account for 90.89% of the total landings. Motorized boats contribute a smaller share, making up 9.1% of the catch. Non-motorized boats have a negligible impact, representing only 0.01% of the total fish landings along the Gujarat coast. This data highlights the dominant role of mechanized boats in the region's fishing industry (CMFRI, 2022).

The Gujarat coast features several prominent and bustling marine fish harbours and landing centres that play a crucial role in the state's fishing industry. Key amongst these are Veraval, Mangrol, Porbandar, Okha, and Jakhau. These centres are vital for their significant contributions to the total fish landings in Gujarat (Fig. 1.3), making them central hubs for fishing activities in the region. Their operational scale and efficiency underscore their importance in supporting the local economy and the livelihoods of communities engaged in fishing.

In Gujarat, elasmobranch fishing primarily occurs as bycatch in various fisheries targeting other species. Despite the ecological and economic significance of elasmobranchs, there is a notable lack of comprehensive data on their populations and bycatch rates. This gap in information poses challenges for effective management and conservation of these vulnerable species.

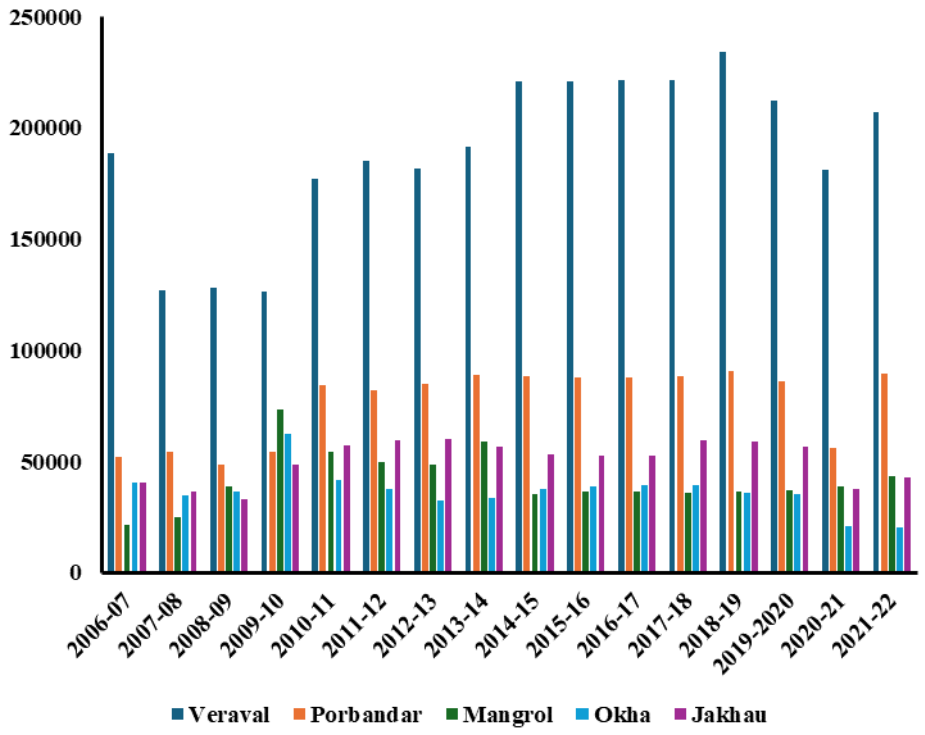

Figure 1.3: Important Marine Fish Landing Centres and its Production from 2006-07 to 2021-22 (Source: Fisheries statistics of Gujarat 2021-2022)