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RECONSTRUCTION OF INDIA'S MARINE FISH CATCH FROM 1950-2010

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ABSTRACT

The Republic of India, located in South Asia, is a country that is mostly surrounded by ocean. It has 28 states (9 maritime) and 7 union territories (4 maritime). With a total population currently exceeding 1.2 billion people, India is the second most populous country in the world. There are marked oceanographic differences between the east and west coasts. However, both the Bay of Bengal on the east and Arabian Sea along the west coast provide rich marine resources to coastal communities. This study aims to evaluate the current status of India's marine fisheries by presenting a reconstruction of total marine fish catch from 1950-2010 (the Andaman and Nicobar Island group is not included here, and is covered elsewhere). It was found that total extractions, by all sectors from within India's mainland EEZ were over 155 million tonnes, i.e., over twice the 75 million tonnes reported by FAO on behalf of India. The industrial sector, with over 54 million t was deemed the largest sector over the full time period, while the unreported subsistence sector was estimated at nearly 51 million t, followed by the artisanal sector with nearly 50 million t. Illegal fishing and 'fishing down' were both identified as being major threats to India's fisheries, and without changes to local monitoring and offshore enforcement, they will continue to operate at an unsustainable levels.

INTRODUCTION

The Republic of India is a South Asia country bounded by oceans and located between latitudes 8° 4' and 37° 6' N and longitudes 68° 7' and 97° 25' E (Figure 1). It shares land borders with Pakistan on the west, China, Nepal and Bhutan to the north, and Burma and Bangladesh to the east. India is the second most populous country in the world, with approximately 1.2 billion people (2011 census), and contains 17.5% of the total world population.[1] With 28 states (9 maritime) and 7 union territories (UT; 4 maritime), India covers a total land area of about 3.3 million km^2 (Arora and Grover 1996). The west coast of India has 5 maritime states: Gujarat, Maharashtra, Goa, Karnataka, and Kerala (1-5, Figure 1) and two UTs, Daman and Diu, and Lakshadweep. The east coast of India has 4 maritime states: Tamil Nadu, Andhra Pradesh, Orissa, and West Bengal (6-9, Figure 1). The UTs in the east include Pondicherry and the Andaman and Nicobar Islands, the latter not covered here. The marine waters of India encompass two Large Marine Ecosystems (LMEs), the Arabian Sea along the west coast and the Bay of Bengal along the east. India's Exclusive Economic Zone (EEZ) covers a total area of 1.63 million km^2 (including the Lakshadweep

[1] http://www.censusindia.gov.in/2011-prov-results/data_files/india/Final_PPT_2011_chapter3.pdf

Islands on the west coast). As with most developing countries with vast coastlines, the rich resources of the surrounding ocean play an important role in the national economy, diet and culture of the Indian people.

The marine fishing sector in India has shown steady growth since India's independence in 1947. India's 200 nautical mile EEZ was declared in 1976. The fisheries in west and east India are characterized by noticeable differences in terms of the types of vessels, number of fishers and available resources (Flewwelling and Hosch 2006). The west coast of India, known as the 'Malabar coast', has a wider continental shelf and is known for its high primary production. It supports over 75% of India's total fish landings (Chandy 1970). The east coast, which is also known as the 'Coromandel coast', has a much narrower shelf and primary production and fish catch from the Bay of Bengal are much lower than in the Arabian Sea. Along the extensive coastline, there are approximately 3,827 fishing villages and 1,914 traditional landing centers (FAO 2004). The waters off India are known for their extensive diversity of marine resources and traditional fishing has been a way of life for many coastal communities

The growth of India's fisheries sector can be separated into three phases (Figure 2) (Bhathal 2005; Srinath and Pillai 2006; Sathianandan *et al.* 2011). In phase one (1950-1966), landings were mainly by non-mechanized traditional crafts and gears, such as hook and line, gillnets, seines, bag nets and traps, from catamarans, canoes and plank built boats. During the second phase (1967-1986), these vessels were modified to hold outboard engines of 5-9 hp (i.e., *motorization*)[2], in order to travel farther and increase fishing effort. In the third phase from about 1987 to 2010, major endeavors were made to further increase *mechanization*[3] and develop the industrial fishing sector (Rao and Murty 1993; Bhathal 2005). Vessels were equipped to engage in multi-day voyages and a large expansion of fishing grounds was observed. Despite this, India's fisheries remain small-scale in nature and difficult to categorise, since boundaries between subsistence (i.e., small-scale non-commercial) and artisanal (i.e., small-scale commercial) sectors are blurred (Flewwelling and Hosch 2006). There are approximately 1.45 million fishers in India and the bulk of marine fish landed (about 70%) is being targeted by mechanized fishing vessels (Funge-Smith *et al.* 2005), which for the purpose of this report are defined as industrial.

Trawling has emerged as the most important method of exploiting demersal resources and accounts for about half of the total Indian catch. Today, the mechanized/industrial fleets consist of small trawlers, pair trawlers, purse seiners and gillnetters. Chartered and joint-venture trawlers, tuna longliners, and other multi-purpose vessels (i.e., that catch prawn and fish), ultimately operated by foreign vessels, make up the bulk of the industrial fleet and have been fishing off India's coastline since 1972 (Devaraj 1996). Valuable species such as Indian oil sardine (*Sardinella longiceps*), penaeid and non-penaeid shrimp, Indian mackerel (*Rastrelliger kanagurta*), Bombay duck (*Harpadon nehereus*) and croakers (*Micropogonias*

[2] Within the Indian context "motorization" refers to outboard engine propulsion, replacing or added to sails and oars of traditional craft; fishing operations are carried out manually.
[3] "Mechanization" refers to the deployment of fishing crafts equipped with inboard engines.

spp.) are the primary targets, although various types of commercial finfish are often caught as by-catch (Gordon 1991).

Large quantities of prawn and shrimp resources are also caught along the coasts of India in major estuaries, creeks, brackish water lakes and backwaters. The most important estuaries are the Sundarbans in West Bengal, and Godavary in Andhra Pradesh, each are estimated to produce approximately 1,000 t of shrimp catch per year. The Chilka, in Orissa and the Pulicat, shared by Madras and Andhra Pradesh, are vital brackish water lakes also know to yield about 1,000 $t \cdot year^{-1}$. The most important backwater is the one in the Cochin area of Kerala, with an estimated annual yield of over 10,000 t (Jones 1968). On the northeast and west coast, prawn species are abundant and form a major portion of the subsistence fishery (Jones 1968). The magnitude of the estuarine and backwater fishery for the entire country is notable, yet the cumulative catch from these areas has not been estimated (Rao 2000).

The first offshore policy was developed in 1977, in hopes to initiate chartering arrangements with foreign companies. However, the Maritime Zones of India (Regulation of Fishing by Foreign Vessels) Act came into effect in 1981 to regulate fishing by foreign fishing vessels in India's EEZ (Bhathal 2005). The number of large trawlers increased from 37 in 1978 to 180 in 1991, most of which operated off the east coast from Visakhapatnam (Rao 1988; Kurien 1995; Devaraj 1996). By the early 1980s, about 110 chartered and joint-venture vessels were exploiting inshore grounds up to 50 m (Kurien 1995; Devaraj 1996). In 1983, depth restrictions beyond 80 m were enforced which resulted in many foreign vessels leaving the country, as most were targeting valuable shrimp species found inshore. The 'Deep Sea Policy (1991)' set the stage for further foreign influence; however, the policy was rescinded in 1997 after protests from local fishers forced the government to halt administering licenses to joint-venture companies (MOEF 2002).

The marine fisheries in India are regulated both by the Central and State Governments. Offshore fishing within India's EEZ by domestic and foreign fleets is managed by the Central government. However, there is no comprehensive fisheries legislation (Rajagopalan 2011). Fisheries within the 12 nm territorial zone fall under the jurisdiction of the States, which are responsible for managing and collecting official fisheries statistics under the *Marine Fishing Regulation Act* (MFRA) (Bhathal 2005; Rajagopalan 2011). Along with State governments, the Central Marine Fisheries Research Institute (CMFRI, www.cmfri.org.in) estimates the annual fish landings by state and compiles the data for the entire country. National catch statistics prior to 1994 were put through a rigorous statistical sampling procedure; however, since the mid-1990s, changes to the sampling program caused deterioration of India's marine production statistics (Malhotra and Sinha 2007; Bhathal and Pauly 2008).

The national data collected by the CMFRI were used as a baseline to reconstruct India's total marine fisheries catches from 1950-2000 (details in Bhathal 2005), as most data published by other institutes and departments were not available. India regularly reports commercial landings from the artisanal sector.

However, industrial landings have historically been unreported in the national data. Bhathal (2005) estimated total catch by industrial vessels from 1972-2000, since the first commercial trawlers arrived in India's waters and began operation in 1972 (Devaraj 1996). Industrial and mechanized vessel discards were also estimated, as they are rarely reported to designated institutes (Bhathal and Pauly 2008). However, these estimates were considered to be conservative compared to previous reports on by-catch and discards in India (Gordon 1991; Davies *et al.* 2009; Dineshbabu *et al.* 2010). Furthermore, it was assumed that all by-catch was retained prior to 1970, as even low value species had a market, resulting in negligible discards (Bhathal 2005).

An attempt at estimating fishery extractions, including illegal and unreported catches from India can be found in Pramod (2012). Estimates of illegal fishing by Indian and foreign vessels, discards by industrial trawlers, subsistence fishing, and underreporting by the artisanal sector were estimated during a 2008 field study. Pramod (2012) conducted interviews with fishers from the small-scale and mechanized sector, in 9 out of 10 coastal states[4] and in the Andaman and Nicobar Islands. In addition to reported catch, Pramod (2012) findings suggested that approximately 1.5 million tonnes were unreported in 2008. The highest unreported catch (approximately 1.2 million tonnes) was contributed by discarded by-catch from industrial vessels. Often the low quality by-catch is discarded at sea in order to save space for storing shrimps and valuable finfish (Devaraj 1996). Subsistence fishing, which is entirely missing from the catch statistics (Morgan 2006), was very conservatively estimated at 149,000 t for the entire country, and underreported catch within the artisanal sector was conservatively estimated at about 105,000 t. Pramod (2012) also estimated discards by foreign-chartered trawlers and Letter of Permission (LoP) tuna longliners, fishing within India's EEZ intermittently from 1982-2009. Recreational catch by part-time fishers and catches from remote fish landing centers, which are poorly monitored by government officials, were incorporated into Pramod's field study; however, individual estimates for these sectors were not given.

According to the United Nations Food and Agriculture Organization (FAO), which has been compiling annual catch data worldwide since 1950, reported landings by India have increased from 530,000 tonnes in 1950 to approximately 3.2 million tonnes by 2010[5]. In 2008, the country ranked eighth in global marine fisheries catches. Currently, increased fishing pressure by excess fishing capacity results in overfishing and fishing down the food web (Bhathal and Pauly 2008), and has depleted inshore resources and increased catch of juveniles and discards (Somvanshi 2001; Sathiadhas 2005). It is apparent that the status of marine fisheries in India must be critically evaluated. Therefore a further breakdown of India's total marine exactions is useful. The methodology and detailed taxonomic breakdown from Bhathal (2005), serve as a foundation for the reconstruction of Indian catches to 2010. The information on discarding,

[4] Goa and the union territory of Daman and Diu were not visited on this study. Information from the Lakshawdeep Islands was under review at the time Pramod (2012) was writing and therefore not included either.

[5] Fishstat database http://www.fao.org/fishery/statistics/en.

subsistence and illegal fishing by foreign fishers presented by Pramod (2012) will also be used in the present study to enhance estimates of unreported catches from India's waters.

METHODS

National marine landing statistics

The Ministry of Agriculture collects, collates and compiles data on marine fish landings and fishing fleets through the state governments, fisheries departments and central institutions like the CMFRI and the Fishery Survey of India, or FSI (Malhotra and Sinha 2007). Under the Ministry of Agriculture, it is the responsibility of the Department of Animal Husbandry, Dairying and Fisheries (DAHD) to report national fisheries statistics to international agencies, such as the FAO. Regarding the coastal fishery around mainland India, the CMFRI collects data on fish landings through a stratified multi-stage random sampling procedure (Somvanshi *et al.* 1999; Srinath *et al.* 2006; Malhotra and Sinha 2007; Vijayakumaran and Varghese 2011). It has been noted that fish production estimates are not very reliable, and due to the long coastline, widely dispersed landing sites and diversity of fishing practices, finding accurate catch statistics is challenging (Malhotra and Sinha 2007).

Discrepancies have been observed between the reported FAO catch statistics and national data presented by the CMFRI (Moreno *et al.* 2012; Figure 3). Based on personal communications (to B. Bhathal) by personnel of the Indian Council of Agriculture Research (ICAR), either CMFRI data or one collected independently by the State Fisheries Departments are sent to FAO through the Ministry. In earlier years, the State Governments obtained required statistics from the CMFRI; however, over time they gradually started their own data collection. It is unknown when this transition may have occurred, but it is one explanation for the inconsistencies in catch data. In addition, the FSI has been collecting data on exploratory fishing of oceanic tuna resources in the Indian and Andaman and Nicobar EEZ, as well as catches from foreign chartered and joint-venture operations (Somvanshi *et al.* 1999; Vijayakumaran and Varghese 2011). The catches by chartered vessels flying Indian flags are reported on behalf of India, and since the national CMFRI data do not include offshore industrial catch (Bhathal 2005), this may contribute to the reported catch by FAO being higher.

Fisheries statistics are collected only from important landings places, although species that are destined for export are recorded at the point of sale or export (Flewwelling and Hosch 2006; Morgan 2006). The quality of monitoring by government, municipality or corporative bodies at any point remains poor. In addition, improper handling of fish products at the wholesale markets results in poor quality of fish and high amounts of unwanted species that are either discarded or used for fishmeal production (Kumar *et al.* 2008). At the majority of landing sites, all species are landed, whether for local consumption or export. Due to this system, it has been recognized that at times aquaculture production may have been erroneously incorporated into the official capture statistics (Morgan 2006). In addition, it has been noted that fish originating from subsistence fishing, as well as catches originating from estuaries and backwaters (Pramod 2012), are not included in the statistical collection (Morgan 2006). These issues of

underreporting of India's marine catches, suggest that national catch statistics, and therefore the fisheries statistics provided to the FAO, are incomplete and must be examined with caution.

Fishing sectors

Marine resources in India are targeted by four main fishery types, operating various types of fishing vessels and gears: (1) artisanal fishers operate non-motorized vessels, (2) artisanal fishers operating motorized vessels (with outboard motors of less than 50 hp) in inshore waters, (3) industrial fishers using mechanized vessels (with inboard motors), and (4) industrial deep-sea vessels (Bhathal 2005). Sector-wise landings as described in the annual CMFRI reports (1957-2010), were used to separate the total marine catch using proportional breakdown by sector and year. It was assumed that, from 1950-1952 the artisanal sector landed 100% of catches. Due to a gradual shift to vessels with motors, an increase in landings was observed (Figure 2); resulting in both sectors (non-motorized and motorized) contributing to the artisanal catch from 1952-1972. After 1983, landings from the artisanal sector begin to decrease as phase three of India's development plan was initiated. The number of industrial vessels steadily increased from the mid-1970s to 2010, and the proportion of catch by the industrial sector (excluding industrial shrimp) increased from zero in 1980 to 71.1% in 2010.

Industrial fisheries

Unlike most developing countries, India has never signed fisheries access agreements with distant water fishing nations (DWFN) and has worked for decades to develop its own domestic industrial fishing fleet (Flewwelling and Hosch 2006). The expansion of India's small-scale fishing sector, which operates in inshore waters, slowed substantially by 1970, while mechanized fishing in offshore waters increased (Bhathal 2005). However, the CMFRI failed to obtain catch data from large-scale industrial vessels (M. Srinath, pers. comm. 2004). Due to the inconsistencies and discrepancies in catch statistics (Moreno *et al.* 2012), it is likely that the DAHD or FSI is compiling data and reporting on behalf of the industrial fishery to the FAO, resulting in higher catches in some years (Figure 3). In order to account for misreporting issues, it was assumed that the differences in tonnage (most importantly for large pelagics from 1974 to 2007) were from large-scale industrial vessels fishing outside India's EEZ and reported to the FAO by an agency other than the CMFRI.

Shrimp fishery

Crustaceans (prawn and lobster), form the most economically important resource in the marine landings in India (Jones 1968; Radhakrishnan 2008). Small-boat shrimp trawling started on the west coast in the early 1970s. It was estimated that out of the 875,400 t of marine fish caught in 1957, approximately 16% (136,800 t) were contributed by the prawn and shrimp fishery, but this decreased to approximately 10% by 1970 (Jones 1968). The economically important prawns constitute the major portion of catches; these include *Penaeus*, *Metapenaeous*, *Parapenaeopsis* and *Solenocera* shrimp. In addition, non-penaeid species belonging to the genera *Palaemon*, *Hippolysmata*, and *Acetes* are also caught.

Shrimp landings and underreported industrial catch (i.e., shrimp catch) were previously estimated by Bhathal (2005). However, these estimates are now considered too conservative; thus when added to the CMFRI national data, they were lower than the catch reported to FAO in the early-1950s and 1970-1980. In years when the reconstructed total was less than the reported FAO landings for 'natantian decapods nei', the FAO total was accepted as is. Updated state shrimp data from the CMFRI was used from 2001-2005, and from 2005-2010 the FAO reported landings were accepted as is.

Besides the industrial trawl fishery, substantial quantities of prawns are caught with traditional gears in various estuaries, tidal creeks, brackish water lakes and backwaters along the coast (Panikkar and Menon 1956; Jones 1968; Radhakrishnan 2008). It was assumed that the artisanal contribution to shrimp landings would be 100% from 1950-1958, and would gradually decrease to 17% in 1974 (Silas *et al.* 1984). The industrial contribution to this fishery increased to 96% by 1990 and was held constant to 2010.

Giant tiger prawn

Giant tiger prawn (GTP; *Penaeus monodon*) is the largest Indian marine prawn, and is more common along the east coast, especially the northern sections of West Bengal and Orissa. On the west coast, it is caught in very low quantities, mostly in the north (Panikkar and Menon 1956; Jones 1968). FAO reported an increase in landings of giant tiger prawn from the west coast from the late 1980s to 1990s. This is primarily a cultured species on the west coast, suggesting that the reported 'landings' had mistakenly included aquaculture production (Morgan 2006). Landings of GTP are not reported in the official catch statistics until 1988. However, it is likely that prior to 1988 they would have been incorporated into 'natantian decapods nei'. GTP landings from the east coast fluctuated from about 17,500 t·year^{-1} in late 1980s to a peak of about 93,500 t in 2008. Conversely, 73,000 t was recorded on the west coast in 1988 and landings peaked at about 128,000 t in 2008. It has been noted that 92.2% of wild GTP catch originates from the east coast, with the west coast only contributing the rest (Rao 2000). Using these proportions, the FAO west coast reported GTP landings were separated into two categories: wild caught (7.8%) and assumed aquaculture production (Figure 4). This assumed cultured production was subtracted from the reported GTP landings for the west coast, as the present report only considers wild capture fisheries.

Using the adjusted GTP landings, it was estimated that this species contributed approximately 11% to total shrimp landings in 1988 and has increased to 22.5% by 2010. To estimate GTP landings prior to 1988, it was assumed that they would contribute 5% to total shrimp landings in 1950 and gradually increased to 9% by 1988 (Figure 4). The previous breakdown for the east and west coast (92.2% and 7.8% respectively) were applied to the total GTP landings to estimate catches on both coasts from 1950-1988.

Discards

The practice of discarding shrimp by-catch in India is associated with long distance, multi-day fishing, which applies to trawlers based in Visakhapatnam, Andhra Pradesh (Gordon 1991; Zacharia *et al.* 2006). Trawl by-catch is generally not properly cared for, and thus discarded due to improper handling, preservation and processing. According to one estimate, about 130,000 t·year^{-1} of by-catch was discarded by large trawlers alone in the northeast coast of India in 1988 (Gordon 1991; Rao and Murty 1993). Industrial trawlers do not keep any records of their discards and the amount of by-catch discarded at sea can vary by vessel, haul and season (Rao 1988).

Few studies have been conducted on by-catch and discards from Indian waters (George *et al.* 1981; Gordon 1991; Zacharia *et al.* 2006; Dineshbabu *et al.* 2010). However, the earliest survey of by-catch in India found that 79% of the total landings in the shrimp trawl fishery consisted of non-shrimp catch (George *et al.* 1981; Silas *et al.* 1984). By-catch estimates tend to vary among states (Boopendranath *et al.* 2010). However, the data available suggest that one third of all by-catch is discarded (Davies *et al.* 2009). Another source suggests that 20% of by-catch is lost, although this may be a conservative estimate (Chandrapal 2007). It has been suggested that discards have declined since the 1990s, due to a reduction in fleet size and catch of shrimp (Kelleher 2005). However, according to Pramod (2012), an estimated 0.9-1.5 million tonnes are still discarded annually in the eight coastal states, representing about 32-53% of the reported catch for India.

Discards and retained by-catch for the shrimp trawl fishery were calculated using reconstructed industrial shrimp landings by state as described above. A 1:4 ratio of shrimp to by-catch was applied to all state industrial shrimp catch from 1950-2010. Using information from Davies *et al.* (2009), it was estimated that 33% of all by-catch was discarded from 1950-2010. Discards are considered to be negligible in non-motorized fisheries and very low in motorized artisanal fisheries (Kelleher 2005). However, mechanized (i.e., industrial) vessels discard unwanted species (Gordon 1991). Therefore, as done by Bhathal (2005), it was assumed here that 2% of India's total marine catch, excluding industrial shrimp, was discarded from 1950-2010.

Artisanal fisheries

The three largest artisanal fisheries on the west coast are Indian oil sardine, Bombay duck *(Harpadon nehereus)* and prawn fisheries, while the main stocks exploited on the east coast include lesser sardines (*Sardinella* spp.), silverbellies (Leiognathidae), penaeid shrimp, croakers (Sciaenidae), *Hilsa* spp., and catfishes (Ariidae). Today, the main fisheries on the west and east coast are highly mechanized (i.e., industrial) and the traditional, non-motorized sector contributes less than 5%. For this report, the artisanal sector consists of the non-motorized and inshore motorized fishing fleets.

Landing of fish takes place at numerous locations along the coast, both day and night. There are about 3,200 marine fishing villages and about 1,300 landing centers along the mainland coast (Srinath *et al.* 2006). Out of these landing centers, about 100 are considered 'major', i.e., centers that handle India's commercial marine catch of approximately 3 million tonnes (Srinath *et al.* 2006). The CMFRI describes the use of a sampling method to quantify landings across all landing centres, and collect and submit the data for the coastal fisheries on a monthly basis (Srinath *et al.* 2006; Malhotra and Sinha 2007). Issues with this type of data collection include: no distinction of the type of gear used, the type and number of boats are often ignored and species-specific catch data are often aggregated under a broad category, e.g., 'billfishes' (Moreno *et al.* 2012).

Misreporting of India's marine catches has been observed to differ along the coast and among different fishing sectors. For example, the Government of Kerala made note of the difficulties in monitoring marginal fisheries; thus, there is no organized landing procedure for brackish water catches, which are typically brought directly home or taken to nearby coastal markets (Pramod 2012). According to Pramod (2012), for many small-scale landing centers along the east coast, catches, which are sold as 'lots' (i.e., heaps of fish) were never weighed or recorded. In addition, interviews with fishers revealed that catches by unregulated or unlicensed fishing boats, in both the artisanal and industrial sectors, are not quantified or accounted for in the reported catch statistics.

The total catch contributed by the artisanal sector was calculated using a proportional breakdown, as described earlier. To account for issues of mis/underreporting within this sector, artisanal catches (including catch of shrimp by artisanal fishers) were conservatively increased by 10% from 1950-1990. As previously mentioned, the CMFRI statistical collection and sampling procedure has shown deterioration since the mid-1990s. It was therefore assumed that underreported catch from the artisanal sector would increase gradually to 22% of the total catch in 1995, and remain in that range to 2010.

Molluscan catch

Many traditional artisanal vessels fishing for mollusks along India's coast are unregistered. Also, much of the molluscan catch from the shore, in mangrove and backwaters using shore seines, drag nets, push nets and cast nets remains unrecorded (Kurien and Willmann 1982; Pramod 2012). Interviews with Fisheries Department staff have confirmed that in some coastal states, there is not enough staff or budget to quantify molluscan catch from remote areas (Pramod 2012). Pramod (2012) estimated that 42,420 t of molluscs were harvested in 2008 and Suja and Mohamed (2010) have estimated that in the state of Kerala alone, about 66,000 t of clams were landed in 2008-2009. The official reported landings for molluscs are currently about 7,000 $t \cdot year^{-1}$.

Using the official FAO data for 'marine molluscs nei' (reported from 1981-2010) and the estimate for 2008 from Pramod (2012), it was conservatively estimated that about 80% of molluscan catches were unreported. This unreported proportion was applied to all catches from 1981-2010. In 1981, reported

landings were 50 t and then jump to 1,320 in 1981. It was therefore assumed that in 1950 total molluscan catch (reported and unreported component) would be 250 t and was linearly interpolated to the total catch derived in 1982 to estimate unreported catches from 1950-1980.

Subsistence

Fishing communities rank amongst the poorest in India, and the push for modernization of the traditional fishing fleets has reduced the production for home consumption and local markets, and shifted the focus to international markets (Johnson 2001; Flewwelling and Hosch 2006; Sathiadhas *et al.* 2012). The tribal population of the Sundarbans, the largest mangrove forest in the world, depend on its rich resources of shrimp and other aquatic species (Das 2009). Thousands of people are engaged in shore-based fishing for personal consumption, or sale in domestic market or export. The shore-based fishers in India, many of them women and children (Koshy and Sharma 2007), are amongst the most marginalized and vulnerable fishing populations.

Fish products intended for home consumption are not included in official Indian statistics, although they represent a substantial component of marine fishery extractions (Morgan 2006). Thus, interviews by Pramod (2012) with government officials and subsistence fishers revealed that catches by this sector are rarely quantified, due to shortage of personnel and the opportunistic nature of this sector. In addition, certain fisheries targeting demersal species also catch reef-dwelling species; however, due to the multi-species nature of the fishes and since much of it is for subsistence, these catches have been poorly documented as well (Rajasuriya *et al.* 2000).

Following Pramod's field study, subsistence[6] estimates were derived from a small sample of sites (estuaries, backwaters or creeks) from each state and were not scaled up to reflect total subsistence catch for the entire country. For example, the state of Gujarat has 14 coastal districts and four out of the five total locations sampled from Gujarat were from the same district. Taking this into consideration, it was assumed that the subsistence estimates conservatively only represented 10% of the total subsistence catch of each state. All state estuary and reef-based subsistence estimates were scaled up to account for the un-sampled districts (Table 1). The take-home catch of artisanal fishers was also included in the subsistence estimate. Using the average take home catch per trip provided by Pramod (2012), the average take-home catch for each state was re-calculated using the average trips per year (88.3) for artisanal fishers (Kurien and Willmann 1982) and the number of fishing households in each state (Table 1). Also included in Pramod (2012) were estimates for trawlers' take-home catch and fish consumption at sea, which were included in the subsistence estimate and accepted as is.

[6] Subsistence fishing, as defined by Ganapathiraju (2012), is "localized fishing in inshore habitats (backwaters, creeks, intertidal areas) using traditional gears like push nets, cast nets and line etc. primarily for consumption at home and survival on a daily basis, without intention to generate profit or intend for commercial sale purposes."

To estimate Indian subsistence catch from 1950-2010, we derived a *per capita* subsistence catch rate using the scaled-up subsistence catch estimate from 2008 (Table 1) and the coastal rural population data supplied by NASA's Socioeconomic Data and Applications Centre, or SEDAC (CIESIN 2012). The population data was presented by either coastal rural or urban locations, with a distance from the coastline of between 5 and 200 km. We chose 10 km for the limit of marine subsistence effort, resulting in a coastal subsistence rate of 13 kg·person^{-1}·year^{-1}. Data on coastal population were only available for the years 1990, 2000 and 2010; linear interpolations were used for years without data. To estimate coastal population in earlier years, the proportion of people living on the coast in relation to India's total population from 1990 was derived and applied to the total population from 1950-1990. Country wide population data were obtained from the Government of India's Census department,[7] which was completed every ten years starting in 1961 (Figure 5). In years with missing or incomplete data, population estimates were gathered from the historical demography website[8] or the World Bank.[9] Interpolations were used for 1982-1985, 1991-2001, and 2001-2006.

Pramod (2012) suggests that prior to 1990, "subsistence fishers engaged in fishing throughout the year, while in recent decades they find it difficult to eke out a living from fishing alone and are increasingly compelled to work as manual daily wage labour in construction, agriculture and aquaculture for certain periods of the year." Taking this into account, the 1990 rate was increased by 50% to 20 kg·person^{-1}·year^{-1}, and for 1950, a rate of 40 kg·person^{-1}·year^{-1} was assumed; rates were interpolated between anchor points. The 2008 rate was held constant to 2010. The *per capita* subsistence catch rates were applied to the 10 km coastal population to estimate India's total subsistence catch from 1950-2010.

Tuna fishery

India's tuna fishery consists of:

- A coastal fishery, mainly by artisanal fisheries using motorized boats but operating a number of traditional gears;
- An artisanal pole and line fishery based in the Lakshadweep Islands;
- Small-scale longliners (mainly converted shrimp trawlers) targeting tuna within the EEZ;
- An industrial longline fishery by joint-ventures (LoP Taiwanese vessels), targeting tuna off the northwest coast and in the Andaman and Nicobar Islands.[10]

Coastal and oceanic tuna

Catch data for the tuna fishery included previously reconstructed totals from 1950-2005 (Bhathal 2005) and landings data supplied by the CMFRI from 2006-2010. The CMFRI reports five categories of tuna: kawakawa (*Euthynnus affinis*), frigate and bullet tunas (*Auxis* spp.), skipjack tuna (*Katsuwonus pelamis*), longtail tuna (*Thunnus tonggol)* and an 'other tunnies' group. The FAO provides data on these species,

[7] http://censusindia.gov.in/ [accessed May 7, 2013].
[8] http://www.populstat.info/[accessed May 7, 2013].
[9] http://data.worldbank.org/[accessed May 7, 2013].
[10] Andaman & Nicobar contributes about 2.2% to the national tuna landings. Coastal tuna catch for the islands were subtracted from India's reconstructed tuna catch and will be presented in a separate study.

except it includes a separate category for landings of bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*), which are likely incorporated into the 'other tunnies' group in the national data. Catch data reported by the two agencies are generally the same from 1950-1970; however, from 1970-2010, the FAO totals are higher for most years. It was assumed that the national data for tuna represented catch by the coastal fishery (i.e., primarily artisanal) and the difference between the FAO and reconstructed data would represent catches outside of the EEZ by the oceanic (industrial) fishery, likely not reported by the CMFRI. The oceanic tuna catch in 1950, of 2 t, was linearly interpolated to 1970 (487 t) to represent a gradual increase in mechanized vessels targeting oceanic tuna species.

The amount of tuna caught by coastal and oceanic fleets has been analyzed from 1990-1997 (Anon. 1999; Somvanshi *et al.* 1999) and from 2006-2010 (Abdussamad *et al.* 2012). It was estimated that yellowfin tuna catches by coastal fleets amounted to about 27,300 t·year^{-1} and the oceanic fleet about 82,530 t·year^{-1} from 2006-2010. However, FAO reports only about 17,200 t·year^{-1} for the same time period, suggesting that the landings for the oceanic fleet are underreported. Using this information, it was assumed that only about 16% of yellowfin tuna catch is reported and 84% (mainly from the oceanic fishery) is unreported. Using this percent breakdown, total unreported catch of yellowfin tuna by the oceanic fishery was estimated from 1970-2010, as it was likely that prior to this catches would have been targeted by traditional vessels that did not operate outside EEZ-equivalent waters.

Of the tuna catch landed by these vessels, kawakawa, skipjack and yellowfin tuna are the most common catches of the coastal fishery, while for the oceanic fishery, yellowfin and skipjack make up the majority of the catch (Somvanshi *et al.* 1999; Vijayakumaran and Varghese 2012). The by-catch associated with this fishery is about 49% of the total catch and was calculated for both the coastal and oceanic tuna fishery. Important species within the by-catch are billfish (*Istiophorus platypterus*, *Makaira indica* and *Xiphias gladius*), seerfish (*Scomberomorus commerson*, *S. guttatus*, *S. lineolatus*, and *Acanthocybium solandri*) and sharks (Somvanshi *et al.* 1999).

Joint-venture longliners

From 1985-1995, over 200 Taiwanese joint-venture (LoP) vessels were licensed to operate in the Indian EEZ, exploiting offshore tuna resources, specifically yellowfin tuna (Shajahan 1996; Flewwelling and Hosch 2006; Pramod 2012). The key fishing areas for these fleets are located off the north-west coast of India and within the waters of the Andaman and Nicobar Islands. Catch data for the industrial tuna fishery can be traced from voyage reports received by the FSI from these tuna longliners operating under the LoP scheme. According to the Indian Ocean Tuna Commission (IOTC), all catches made by joint-venture operations registered under the Indian flag are reported as domestic to the IOTC. Therefore, it was assumed that the joint-venture tuna catch from 1986-2010 was reported to the appropriate agencies (including FAO) as domestic.

Interviews with joint-venture longliners have suggested that only 20% of the actual catch caught during the year is reported and by-catch is rarely reported (Pramod 2012). The rationale supporting this claim is that the total amount of tuna landed by these vessels does not even cover the operating costs of the vessel, let alone profit from the catch (Rao 2009; Pramod 2012). These vessels have also been observed to engage in 'flag hopping' and will operate under an Indian flag in Indian waters and then switch to a Taiwanese flag in international waters. This is done to illegally tranship the tuna catch caught from the Indian EEZ at sea (Pramod 2012).

Information on the catch and by-catch contributed by LoP tuna vessels were available from 1983-1998 (Somvanshi *et al.* 1999) and from 2008-2009 (John and Pillai 2009; Vijayakumaran and Varghese 2010). The reported catch in 1998 was interpolated to 2008, as no other information was available for those years. It was also estimated that 80% of the total catch (tuna plus by-catch) went unreported. This unreported proportion was applied to all LoP longline catches from 1986-2009. The catch from 2009 was carried to 2010.

Foreign fishing

Industrial fishing has been dominated by foreign chartered or join-venture fishing companies from Taiwan, China and Thailand (Anon. 1999). Owing to the fact that these vessels often land their catch outside of India, the actual take of these industrial vessels is relatively unknown (Flewwelling and Hosch 2006). It has been documented that these vessels undertake long fishing trips, rarely return to registered ports and are believed to also transship their catch at sea (Abdussamad *et al.* 2012; Pramod 2012). Illegal catch by foreign fishing vessels was observed to be as high as 60,000 t annually, combined with an estimated 1,840 $t \cdot year^{-1} \cdot vessel^{-1}$ (i.e., 8 t per day x 230 fishing days) of discarded by-catch (Devaraj 1996; Pramod 2012). A detailed analysis of the discrepancies of foreign joint-venture and chartered tuna longliners can be found in Pramod (2012).

Chartered tuna longliners

Fishing under the charter scheme was introduced in 1985 and peaked (about 12,570 t of mostly yellowfin tuna) in 1990. The fleets comprised mainly Taiwanese-origin vessels flying flags of Panama or Honduras (Somvanshi *et al.* 1999). Although joint-venture operations registered under the Indian flag are reported as domestic to IOTC, chartered vessels that no do fly the Indian flag are apportioned to the flag country. However, this may not always be the case, as concerns have been raised to possible double reporting of the catch in India and Taiwan's statistics for these chartered vessels (Anon. 1999).

Fishing effort and catch by chartered vessels was available from 1985-1995 (Somvanshi *et al.* 1999). As joint-venture and Indian ownership agreements became more popular, the charter scheme was gradually phased out between 1992 and 1995. Catch composition of these vessels consisted of yellowfin tuna (69%), bigeye tuna (*Thunnus obesus*) (4%), billfish (19%) and other fishes, primarily sharks (8%). Catches were

assigned to the flag country of Panama and Honduras. Due to a lack of flag-specific information, 50% of the catch was assigned to Panama and the other 50% to Honduras. Discards from foreign-chartered tuna longliners were estimated by Pramod (2012) from 1985-1997. Discard rates were low (0.5-1.2 t·haul^{-1}), mostly accounting for species of sharks of which only the fins were retained. The remaining species caught in the by-catch typically go underreported.

Chartered trawlers

It was estimated during 1982-1983, 110 chartered or joint-venture trawlers operated in the inshore waters along the south west coast and caught about 13 tonnes·vessel^{-1}·day^{-1} (Devaraj 1996). These vessels were also reported to discard their by-catch at a rate of 8 tonnes·vessel^{-1}·day^{-1}. Using these rates, Pramod (2012) estimated the total discards by stern trawlers operating from 1982-1985 and 1990-1995, as well as pair trawlers operating from 1990-1995. Using the total discarded tonnage and the above catch per unit effort (CPUE), we were able to estimate the number of trawlers in operation during these time periods and the total catch.

Although Devaraj (1996) discusses the development of offshore fishing by foreign vessels, there is no mention of the origin of these companies (i.e., country) involved in fishing. Based on Pramond (2010) and other documents (Vivekanandan *et al.* 2006), it was assumed that the catch by trawlers operating from 1983-1985 were primarily Taiwanese. Catch by chartered vessels from 1990-1995 were assigned to Taiwan, Thailand and China in equal proportions.

These may only represent a small portion of foreign countries operating in India's waters, as cases of illegal fishing by South Korean, Pakistani, Sri Lankan and Bangladeshi trawlers have all been documented (Pramod 2012). There is very little information on Chinese vessels fishing in the Indian EEZ (see online supporting material for Pauly *et al.* 2013); however, recently the Sri Lankan government has allowed more than a dozen Chinese fishing vessels to operate under the island country's flag under an agreement called 'distant water fishing' (Martin 2013). These vessels are expected to fish heavily in the Wedge Bank area, which is located between the southern tip of India and Sri Lanka.

TAXONOMIC COMPOSITION

Reported data

The taxonomic breakdown for the reported artisanal and industrial commercial catch data were derived from the official catch statistics reported to the FAO and CMFRI on behalf of India (Table 2). The national CMFRI species composition was used to improve general categories in the FAO data, such as the 'anchovies nei' into more detailed genus level i.e., *Coilia*, *Setipinna*, *Stolephorus*, *Thrissina* and *Thryssa* species.

The reported 'marine fishes nei' category includes all varieties of commercially reported taxa, many juveniles, that are caught in small amounts (Rao 1973). All reported taxa (Table 2) were included in the taxonomic breakdown for the 'marine fishes nei', along with information provided in the *Handbook for Field Identification of Fish Species Occurring in the Indian Seas* (Somvanshi 2009). All major families and species not reported by the national or FAO data were included to improve overall taxonomic detail (Table 3). All taxa were cross-referenced with FishBase (Froese and Pauly 2013) to ensure that they do occur in the Indian EEZ, and that currently valid scientific names are used.

Unreported artisanal

The species composition and proportional breakdown for India's marine catch derived by Bhathal (2005), was applied to the estimated unreported artisanal component from 1950-2005 (Table 4). The data and taxonomic breakdown from the CMFRI was used in 2010 and the proportions for each taxon were linearly interpolated from 2005-2010 (Table 4). Species listed in the handbook mentioned above were also incorporated to improve the existing taxonomic segregation and detail.

Molluscan fishery

The CMFRI provided limited catch data on molluscs, which were broken down into bivalves and gastropods for some years (1987-2010). Details regarding the different taxa of molluscs occurring in the India EEZ were found in Somvanshi (2009) and Narasimham (1991). Using this information, the resulting taxonomic breakdown was applied to the unreported molluscan fishery from 1950-2010 (Table 5).

Shrimp fishery

Among the exploited shrimps, penaeid prawns contributes about 60% to country wide shrimp landings. The most commercially important are: giant tiger prawn (*Penaeus monodon*), Indian white prawn (*P. indicus*) and green tiger prawn (*P. semisulcatus*), which combined contribute about 40% and speckled shrimp (*Metapenaeus monoceros*), greasyback shrimp (*M. ensis*) and jinga shrimp (*M. affinis*) contribute 20% each. Of the non-penaeid prawns, which comprise the remaining 40% of total shrimp landings, sergestids (*Acetes* spp.), palaemonids and hippolytids (*Hippolysmata* spp.) are targeted.

By-catch and discards

Information regarding the incidence and composition of finfish and other crustaceans in the shrimp trawl by-catch was provided by Silas *et al.* (1984), Boopendranath *et al.* (2010) and Clucas (1997). This derived taxonomic breakdown was applied to the estimated retained by-catch from 1950-2010 (Table 6).

The discarded by-catch typically includes juveniles and low value species of finfishes, crabs, gastropods, shrimps, cephalopods, jellyfish and stomatopods (Kurup *et al.* 2004). The same taxonomic composition for the retained by-catch was applied to the estimated discards. However, high-value species (Clucas 1997) were given lower proportions and lower-value species such as clupeids, cephalopods, and other

crustaceans, were assumed to have a larger contribution to shrimp trawl discards (Table 6). The other mechanized discards were assumed to consist of unwanted commercial species, and thus the same taxonomic breakdown as the unreported artisanal catch was applied (Table 4).

Subsistence

The taxonomic composition of the subsistence fishery for India was derived from a study of finfishes in the Kali Estuary, Karnataka (Roopa *et al.* 2011), Ponnani Estuary (Bijukumar and Sushama 2000), important species of fish, crustaceans and molluscs of Vembanad Lake, Karala (Suja and Mohamed 2010) and Chilika Lake, Orissa (Mishra *et al.* 2012). As catch composition data were not available at species level, all the major families were selected and assumed to contribute equally. The 41 major families, plus a miscellaneous marine fish category, were then applied to all western and eastern mainland states from 1950-2010 (Table 7).

Tuna fishery

Kawakawa (*Euthynnus affinis*) was the major species, representing 41.9 % of the coastal total tuna catch, followed by frigate and bullet tunas (*Auxis* spp.; 18.9 %), skipjack (*Katsuwonus pelamis*; 17.1 %), longtail (*Thunnus tonggol*; 9.5 %), yellowfin tuna (*Thunnus albacares*; 8.6 %) and bonito (*Sarda orientalis* ; 3.0 %). The offshore fishery is primarily directed at yellowfin and skipjack, with some catch of bigeye tuna (*Thunnus obesus*), kawakawa and longtail tuna.

By-catch related to the coastal and oceanic tuna fishery was almost half of the total tuna catch and consisted of narrow-barred Spanish mackerel (*Scomberomorus commerson),* Indo-Pacific king mackerel (*S. guttatus),* streaked seerfish (*S. lineolatus*) and wahoo (*Acanthocybium solandri*). The first two are the most commercially important, contributing 59.9 % and 39.4 %, respectively, to the total catch of seerfishes (Table 8). Of the billfishes, Indo-Pacific sailfish (*Istiophorus platypterus*), swordfish (*Xiphias gladius*) and marlin (*Istiompax indica*) are the most common. In the offshore fishery for tuna, sharks (25%) (Table 8) are also caught as by-catch (Sivasubramaniam 1985).

Shark catches

The national data for India's elasmobranch catch are reported under one general category from 1950-1980; thereafter, separate categories for sharks, skates and rays are included. The FAO reports one category of 'sharks, rays and skates nei', from 1950-2010. Using the proportional breakdown from previously reconstructed data in Bhathal (2005), the reported landings were divided into sharks, rays and skates from 1950-2005 (Table 9), and the 2005 proportions were extended to 2010.

Species composition of the most important sharks recorded in a tuna longline survey in the Indian and Andaman and Nicobar EEZ (John and Varghese 2009) was used to provide a more detailed taxonomic breakdown for sharks. Shark catches were allocated to the west and east coast and for those designated as

originating outside the EEZ, the taxonomic breakdown for the Andaman and Nicobar Islands was used (Table 10). The same taxonomic breakdown was applied to the unreported shark by-catch from the industrial tuna longline operations.

RESULTS

Industrial fisheries

Reconstructed total catch for the industrial sector amounted to just over 54 million tonnes from 1950-2010 (Figure 6). Reported landings in this sector totaled to over 32.8 million tonnes for the same time period. With mechanization of vessels, landings quickly increased from around 30 t in 1953 to over 102,000 t by 1971. Landings exceeded 1 million t by 1994 and thereafter, were on average 1.4 million t·year^{-1}. Shrimp trawlers dominated the industrial catch and produced over 10 million tonnes from 1950-2010. Total unreported industrial catch, contributed primarily by shrimp trawlers and the offshore tuna fishery (see below) amounted to about 6.0 million tonnes from 1950-2010 (Figure 6). Discards, generated by shrimp trawlers and other mechanized vessels, were estimated to be about 16 million tonnes from 1950-2010 (Figure 6).

Artisanal fisheries

The reconstructed total catch for the artisanal fisheries, including unreported artisanal catch and unreported catches of molluscs, amounted to almost 49.9 million tonnes from 1950-2010 (Figure 7). This excludes coastal artisanal tuna catch and unreported by-catch, which is described below. Official reported landings of artisanal catch totaled to just over 42.7 million tonnes from 1950-2010 and it was estimated that unreported catch was 7.2 million tonnes for the same time period (Figure 7). It was found that lack of proper reporting of the molluscan fishery resulted in an estimated 656,000 t of unreported catch.

Tuna fisheries

Coastal tuna (artisanal)

The artisanal fishery for coastal tuna totaled about 1.4 million tonnes from 1950-2010 (Figure 8). In the early years, landings of tuna were approximately 3,800 t·year^{-1}, increasing gradually with considerable inter-annual variation to a peak of about 82,900 t in 2008 (Figure 8). By-catch from this fishery, which was estimated to be almost half of the total catch of the coastal tuna fishery, was found to produce about 620,000 tonnes of unreported catch (Figure 8).

Oceanic tuna (industrial)

Although the offshore fishery for oceanic tuna was slow to develop, reconstructed total catch (including by-catch) of this fishery amounted to over 4.3 million tonnes from 1950-2010 (Figure 9). Reported catches increased from about 500 t in 1956 to almost 3,000 t by 1980. Landings increased throughout the 1980s as joint-venture operations were introduced. From 2000-2008, average landings decrease slightly to 43,000 t·year^{-1}, then increased again to almost 70,000 t in 2010.

The unreported catch of yellowfin tuna totaled over 1.2 million tonnes from 1970-2010 (Figure 9). This was an evolving fishery and average unreported catch increased from about 8,200 t in 1975 to 25,000 t·year^{-1} by the mid-1980s. Total unreported by-catch produced by this fishery amounted to almost 2 million tonnes from 1950-2010 (Figure 9), of which about 184,600 t originated from joint-venture longlining operations in 1983-2010.

Subsistence

The second largest sector in India, the reconstructed subsistence catch amounted to about 50.9 million t over the 1950-2010 time period. Catches were estimated at 666,000 t·year^{-1} in the 1950s, increased steadily to a peak of 950,000 t in 1990, before declining to 860,000 t·year^{-1} in the late 2000s (Figure 10). The majority of subsistence catches originated from the Kerala state (22%), the West Bengal state (18%) and the Orissa state (15%). While the majority of the subsistence catch originate from the take home catch of the artisanal fishery (61.2%), a fair portion were also reconstructed from estuaries, backwaters and mangrove areas (17.7%).

Foreign fishing

Catch by Taiwanese chartered trawlers fishing in India's EEZ from 1982-1985 totaled almost 622,000 t, while about 382,700 t were discarded (Figure 11). Pair and stern trawlers operating from 1990-1995, caught about 118,000 t and discarded 73,100 t (Figure 11). The combined catch by all foreign countries (Taiwan, China and Thailand) was almost 30,000 t in 1990, but decreased to 1,450 t in 1995.

Total catch (including by-catch) of chartered tuna longliners fishing in India's waters from 1985-1995, amounted to almost 40,000 t (Figure 11). These vessels were reported to discard 6,600 t of by-catch for the same time period. The highest catch of 12,600 t was recorded in 1990; thereafter, an average of 3,900 t·year^{-1} was caught from 1991-1995 (Figure 11).

Reconstructed total catch

The total reconstructed catch by India from within the Indian mainland EEZ was estimated to be over 156 million tonnes from 1950-2010 (Figure 12a; Appendix A1). This total catch by all sectors is over twice the official landings of just over 75 million tonnes reported by India as domestic EEZ catches for the same time period. The industrial sector dominated time series catches, with over 55 million t, accounting for 36% of total Indian EEZ catches. Within industrial catches, landings accounted for 59% (33 million t), while 29% (i.e., 16 million t) were discards and the remaining 6.7 million t were deemed unreported catches. The second largest sector was the subsistence sector, which was not included in the official catch statistics, and which was estimated here to be almost 51 million tonnes and 33% of the total reconstructed catch (Figure 12a). Lastly, the artisanal sector contributed nearly 50 million tonnes and represented 32% of the total reconstructed catch. Within this sector, unreported artisanal catch (including molluscs) and

unreported by-catch from the coastal tuna fishery was estimated to be approximately 7.2 million tonnes from 1950-2010.

The total reconstructed catch from 1950-2010 was dominated by eleven families: Clupeidae, Penaeidae Scombridae, Sciaenidae, Synodontidae, Carangidae, Engraulidae, Leiognathidae, Sergestidae, Trichiuridae and Ariidae (Figure 12b, Appendix A2).

Foreign catches within India's mainland EEZ totalled 1.3 million tonnes, and they were dominated by seven taxa: Penaeidae, Sergestidae, Decapoda, Palaemonidae, Scombridae, Leiognathidae and Sciaenidae.

DISCUSSION

The total reconstructed catch for mainland India's marine fisheries was estimated to be over twice the official landings reported by FAO (about 75 million tonnes within the EEZ) on behalf of India for the 1950-2010 time period. Due to successive subsidy-driven motorization and industrialization (mechanization) schemes , India's domestic fishing fleets and the marine catch they generated have been increasing since the mid-1970s (Figure 12a). The industrial sector contributed 35% of the total reconstructed catch, and is dominated by catches of shrimp, small pelagics and large (offshore) pelagic species such as tuna, billfishes and sharks. This sector generated 21 million tonnes of unreported catch and unreported industrial discards from the shrimp trawl fishery and other mechanized vessels. The subsistence sector, which is not included in any official catch statistics, was estimated to be the second largest sector, with over 50 million tonnes and represented 33% of the total reconstructed catch (Figure 12a). The artisanal (small-scale commercial) sector contributed slightly less than the subsistence sector, i.e., 32% of the total reconstructed catch. This sector has been declining since the 1970s and many coastal species have reportedly been fully or overexploited. Underreported artisanal catch, including molluscs, and large amounts of unreported by-catch from the coastal tuna fishery contributed over 7.2 million tonnes to this sector. Thus, the small-scale fisheries (artisanal and subsistence) accounted for 65% of the total Indian catch, illustrating the significance of small-scale fisheries in India (see also Pauly 2006).

Discrepancies between the national (CMFRI) reported data and the official landings reported to FAO have raised serious concerns regarding the lack of routine monitoring of industrial fleets and LoP tuna vessels. Many species of oceanic tuna and larger pelagics typically caught as by-catch were either underreported or not included within the CMFRI data (such as yellowfin tuna and separate categories for billfish). The FAO database showed a better taxonomic representation for these species. However, it was found that in most cases, large pelagics were still grossly underreported.

The push for modernization of the traditional vessels in India, and the overall marine catch increases observed through the 1980s-1990s (Figure 2) stemmed from a desire to promote the transformation of India's fisheries into more industrial activities (Rao and Murty 1993). The offshore expansion that this

required was viewed as unproblematic, as the assumption was made that rich resources were available in deeper waters. However, the deep waters around India are unproductive, as they are generally oxygen deficient (Banse 1968; Longhurst and Pauly 1987). Therefore, the subsidized trawlers added to the Indian fleets since the 1980s have resulted in increased competition with small-scale fishers operating close inshore. Much of the coastal resources are described as being 'overfished', and the open access regime is identified as one of the main reasons for this current situation (Flewwelling and Hosch 2006). There is also evidence that 'fishing down' has occurred in Indian waters (Bhathal and Pauly 2008).

A study published by the CMFRI (2008) shows an overall decrease in landings of major commercial species and groups such as non-penaeid/penaeid shrimps, ribbonfishes, Bombay duck, threadfin breams and cuttlefishes from 2006-2010. Also, it has been suggested that Bombay duck and pomfrets (Stromateidae) have declined by 25% each, sharks and rays by 28%, and prawns by 35% in the past decade (Rao 2013). One reason behind this is that fishers are more often catching juvenile, under-sized fish, which are driving populations down further. In addition, larger fish like the Bombay duck do not seem to be able to tolerate increasing ocean temperatures, which is affecting fish growth in India and globally (Cheung *et al.* 2012).

Foreign fishing and joint-venture operations have historically been controversial and continue to be a prominent issue for Indian fisheries. The foreign fishery by chartered longline and trawl operations was estimated in this study to account for 800,000 t of catch, with approximately 462,400 t of discards from 1982-1995. This should be taken as a conservative estimate, as detailed information on foreign fishing is scarce and cases of illegal fishing have been frequent in Indian waters (Pramond 2010). Although no foreign flagged vessels are currently allowed to fish within the EEZ, recent reports from Kerala-based fishers have indicated possible entry of 91 foreign fishing vessels into Indian waters; "..this is not a new phenomenon, rather this jack-in-the-box is simply a resurgence of an old problem (Karnad 2012)." It is not known what foreign countries these vessels belong to.

The LoP (joint-venture) scheme introduced in 2002 was thought to correct the major downfalls of the chartered vessels fishing in the 1990s. However, it created a whole new game for foreign companies to abuse, often claiming to be in partnerships with Indian companies to allow for continued fishing in Indian waters. Lack of proper enforcement and regulation of these vessels in and outside of the Indian EEZ, has allowed foreign companies to continue re-flagging and transshipping their catch at sea undetected. Thus, the Indian government lost about 24,000 tonnes through illegal transshipments by Taiwanese owned longliners operating under the LoP scheme in 2007 alone (Pramod 2012). It has been suggested that improved vessel monitoring systems (including compulsory satellite VMS) and strict requirements for LoP vessels to land all their catch in Indian ports before exporting to foreign ports, would help decrease the massive underreporting and economic loss. In addition, all foreign vessels should require 100%

independent onboard observer coverage to better account for catch, by-catch and discards (Zeller *et al.* 2011).

This study, along with previous work (Bhathal 2005; Bhathal and Pauly 2008; Pramod 2012), has highlighted many factors behind the unreporting of catch in the Indian EEZ. Issues such as weak governance, overcapacity in the artisanal and industrial fisheries and insufficient monitoring of foreign chartered vessels, have all contributed to overfishing of the Indian coastal resources. Small-scale fisheries interests have largely been neglected and many coastal communities have been displaced and affected by industrial development and land reclamation (Pramod 2012). The offshore expansion into deeper waters was probably the main reason for the growth then maintenance of Indian fisheries catches (Bhathal and Pauly 2008). However, this expansion must be accounted for when evaluating the health and productivity of Indian fisheries, as true trends in the status of fisheries (e.g., changes in mean trophic level and changes in mean size of fishes) are masked when catch data are not disaggregated spatially (Pauly *et al.* 2012).

Given their spatial expansion, it is apparent that Indian marine fisheries are operating unsustainably. Moreover, the discrepancies described above between actual and official reported landings suggest a need for improvements in the national data collection system, to regularly make and report estimates for poorly and non-monitored sectors to ensure comprehensive accounts of all fishing sector and components (Zeller *et al.* 2007). This study, which provides a more comprehensive analysis of total extractions of India's marine fisheries, also highlights the need for measures, at a local and government level, to reduce effort and increase enforcement, in order to avoid further depletion of resources.

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Table 1: Subsistence estimate for 2008 for the coastal states of India (derived from Pramod 2012).

State	Subsistence catch (t·year^{-1})					
	Estuaries, backwaters & mangroves	Reef based subsistence	Artisanal take-home	Trawler at sea consumption	Trawler crew take-home	Total subsistence
Andhra Pradesh	3,247	730	22,242	5,871	5,167	37,257
Goa/Damian & Diu[a]	-	-	1,815	-	-	-
Gujarat	1,542	990	6,871	2,083	1,833	13,319
Karnataka	825	1,410	7,590	1,248	323	11,396
Kerala	3,632	4,310	46,785	4,796	4,385	63,908
Maharashtra	37	630	10,663	9,061	9,829	30,220
Orissa	9,026	-	32,006	2,361	1,476	44,869
Pondicherry[a]	-	-	2,893	-	-	-
Tamil Nadu	1,809	7,090	29,675	1,355	1,138	41,067
West Bengal	32,296	-	20,897	712	567	54,472
Total	52,414	15,160	181,436	27,487	24,718	

[a.] Subsistence estimates for the states of Goa, Damian & Diu and Pondicherry were not included in Pramod's field study.

Table 2. The percent composition of the reported commercial taxa for the east and west coast of India from 1950-2010.

Taxa		East Coast (%)				West Coast (%)			
		1950	1980	1990	2010	1950	1980	1990	2010
Ariidae	*Arius* spp.	3.2	4.7	6.0	5.7	5.7	7.9	1.8	3.8
Carangidae		4.3	6.0	4.8	4.2	3.3	1.9	10.7	9.5
Chirocentridae	*Chirocentrus* spp.	1.1	3.2	1.3	2.3	0.7	0.6	0.9	0.4
Clupeidae		21.4	27.6	3.9	8.2	13.0	5.4	4.3	2.6
	Sardinella longiceps	0.0	0.0	13.1	8.9	6.5	43.1	21.8	21.2
	Tenualosa ilisha	0.0	0.2	3.6	9.2	0.0	0.1	0.2	1.0
Engraulidae		10.5	9.3	5.0	5.6	9.6	3.9	8.2	5.3
Harpadontidae	*Harpadon nehereus*	0.2	0.5	5.0	2.3	9.1	14.7	11.4	7.5
Lactariidae	*Lactarius lactarius*	0.0	1.0	0.6	0.4	0.0	0.5	0.7	0.7
Leiognathidae		7.5	16.0	12.5	6.7	4.6	3.5	1.1	1.3
Muglidae		0.0	0.5	2.4	0.6	0.0	0.3	0.2	0.1
Mullidae		0.0	0.7	2.7	2.8	0.0	0.1	1.3	0.9
Muraenesocidae		0.0	0.3	0.5	0.6	0.0	1.2	0.3	0.6
Pleuronectidae		0.4	0.4	1.7	2.8	2.3	2.4	2.2	1.1
Polynemidae		0.0	1.4	0.8	0.7	0.0	0.8	0.3	0.3
Sciaenidae		13.7	8.6	3.2	6.3	11.1	4.8	10.9	12.2
Scombridae									
	Rastrelliger kanagurta	0.0	0.0	5.0	4.5	0.0	0.0	10.6	2.8
	Scomberomorus commerson	1.3	1.3	0.7	1.5	1.2	0.8	1.2	1.4
	Scomberomorus guttatus	2.2	2.0	1.4	0.8	0.9	0.5	0.9	0.8
Sphyaenidae	*Sphyraena* spp.	0.0	0.7	1.3	1.1	0.0	0.0	0.1	0.4
Stromateidae		5.3	2.2	3.0	2.7	9.8	2.5	2.3	1.7
Synodontidae		0.0	0.8	0.6	0.4	0.0	0.2	0.6	0.9
Trichiuridae		26.7	6.9	4.7	2.9	19.5	2.6	2.8	10.1
Cephalopods		0.0	0.4	3.1	2.1	0.0	0.1	2.1	7.8
Percoids nei		2.1	3.3	8.4	8.5	1.3	1.4	1.8	4.0
Others[a]		0.1	2.0	4.7	8.2	1.4	1.2	1.3	1.6

[a.] The others category contains nine other minor taxa.

Table 3. The taxonomic composition used to improve the reported FAO 'marine fishes nei' category from 1950-2010.

Taxa		East Coast (%)				West Coast (%)			
		1950	1970	1990	2010	1950	1970	1990	2010
Ariidae	*Arius* spp.	3.5	4.8	6.1	6.2	6.6	9.4	2.1	4.2
Brachyura		0.2	1.2	2.0	5.1	0.1	0.1	0.1	0.7
Bregmacerotidae	*Bregmaceros mcclellandi*	0.0	0.0	0.0	0.0	1.6	0.5	0.0	0.0
Carangidae		4.6	6.2	4.9	4.6	3.7	2.3	11.0	10.4
Chirocentridae	*Chirocentrus nudus*	1.2	3.3	1.3	2.5	0.8	0.7	0.9	0.4
Clupeidae		16.3	13.3	10.2	14.2	10.5	28.6	13.3	13.1
Coryphaenidae	*Coryphaena hippurus*	0.1	2.1	3.3	5.5	0.1	2.4	3.3	5.5
Dasyatidae		0.5	0.6	1.2	1.1	0.6	0.7	1.2	1.1
Drepanidae	*Drepane punctata*	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Engraulidae		10.9	9.4	5.0	6.1	11.2	4.5	8.3	5.8
Ephippidae	*Ephippus orbis*	0.1	1.2	3.1	2.2	0.1	1.4	3.1	2.2
Gerreidae	*Gerres* spp.	0.2	0.5	1.0	1.3	0.3	0.6	1.0	1.3
Haemulidae	*Pomadasys maculatum*	0.1	0.6	0.6	0.7	0.0	0.1	0.1	0.0
Lactariidae	*Lactarius lactarius*	0.5	1.0	0.6	0.4	0.0	0.6	0.7	0.8
Leiognathidae		8.1	16.4	12.2	7.3	5.4	4.2	1.1	1.4
Lethrinidae	*Lethrinus nebulosus*	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1
Loliginidae	*Loligo duvaucelli*	0.1	0.4	3.2	2.3	0.1	0.1	2.1	8.5
Lutjanidae	*Lutjanus* spp.	1.1	5.1	6.1	2.2	1.3	6.0	6.2	2.2
Muglidae		0.1	0.5	2.4	0.7	0.0	0.4	0.2	0.1
Mullidae		0.0	0.7	2.7	3.1	0.0	0.1	1.3	1.0
Muraenesocidae		0.0	0.3	0.5	0.7	0.0	1.4	0.3	0.7
Myliobatidae		2.2	3.1	1.5	0.5	2.3	3.6	1.5	0.5
Pleuronectidae		0.4	0.4	1.7	3.1	2.7	2.9	2.3	1.2
Polynemidae		0.5	1.4	0.8	0.8	0.0	1.0	0.3	0.3
Rachycentridae	*Rachycentron canadum*	1.3	2.1	3.1	2.6	1.5	2.4	3.1	2.6
Rhinobatidae	*Rhynchobatus djiddensis*	0.0	0.0	0.0	0.0	0.1	2.4	3.1	1.1
Sciaenidae		15.2	8.8	3.3	7.7	12.8	11.9	11.2	13.3
Scombridae		3.8	3.5	7.2	7.4	2.4	1.5	13.0	5.4
Sepiidae	*Sepia pharaonis*	0.1	0.5	1.0	0.2	0.1	0.6	1.0	0.2
Sphyraenidae	*Sphyraena* spp.	0.1	0.7	1.3	1.2	0.0	0.0	0.1	0.4
Stromateidae		5.8	2.3	3.1	3.0	11.4	3.0	2.4	1.9
Synodontidae	*Harpadon nehereus*	0.0	0.7	0.6	0.7	0.0	0.2	0.6	1.0
Trichiuridae		21.7	7.1	4.8	3.2	22.7	4.8	2.9	11.0
Miscellaneous marine crustaceans		0.2	0.5	3.9	2.2	0.1	0.1	0.9	0.5
Others[a]		0.9	1.0	0.9	0.9	1.2	1.2	0.9	1.0

[a.] The others category contains nine other taxa with minor contributions.

Table 4. Percent composition of unreported artisanal catch from 1950-2010.

Family / Taxa		% Composition			
		1950	1970	1990	2010
Ariidae					
	Arius caelatus	0.9	2.5	0.8	1.0
	Arius tenuispinis	0.9	2.5	0.8	1.0
	Arius thalassinus	0.9	2.5	0.8	1.0
Carangidae					
	Caranx hippos	1.5	1.7	1.0	1.1
	Caranx para	0.9	0.3	3.0	1.5
	Oligoplites saurus	2.0	0.2	0.1	0.4
	Scomberoides commersonnianus	0.1	0.1	2.1	2.8
	Parastromateus niger	0.6	0.7	0.9	0.7
Chirocentridae	*Chirocentrus dorab*	1.7	0.8	0.6	0.7
Clupeidae					
	Sardinella longiceps	7.3	20.8	11.6	17.1
	Sardinella albella	6.3	2.5	1.7	1.6
	Sardinella fimbriata	6.3	2.5	1.7	1.6
	Tenualosa ilisha	0.5	0.1	0.6	2.9
	Tenualosa toli	0.3	0.9	0.3	0.3
Cynoglossidae					
	Cynoglossus macrostomus	6.3	2.1	1.9	1.6
	Panulirus polyphagus	0.0	0.0	0.1	0.1
	Charybdis cruciata	0.0	0.7	0.8	0.9
	Neptunus pelagicus	0.0	0.7	0.8	0.9
Cephelapoda	*Loligo duvauceli*	0.0	0.1	1.3	3.3
	Sepia pharaonis	0.0	0.1	1.3	2.6
	Octopus vulgaris	0.0	0.1	1.3	0.1
Dasyatidae		0.7	1.4	0.8	0.3
Engraulidae					
	Anchoviella spp.	4.3	2.2	4.2	1.1
	Coilia dussumieri	0.0	0.0	1.5	1.1
	Setipinna taty	0.0	0.0	0.1	0.4
	Stolephorus commersonii	0.1	2.3	2.7	2.8
	Thryssa mystax	1.4	1.3	1.0	0.4
	Thryssa vitrirostris	2.4	1.2	1.1	1.4
	Thrissina baelama	2.4	1.2	1.1	1.4
Exocoetidae					
	Exocoetus monocirrhus	0.5	0.3	0.1	0.1
Lactariidae	*Lactarius lactarius*	1.5	0.7	0.6	0.4
Leiognathidae	*Leiognathus bindus*	1.8	6.9	3.7	2.6
Lethrinidae	*Lethrinus* spp.	0.5	0.1	0.3	0.3
Lutjanidae	*Lutjanus* spp.	0.4	0.1	0.2	0.3
Muglidae	*Liza* spp.	0.0	0.3	0.2	0.2
Muraenesocidae	*Congresox talabonoides*	1.7	0.9	0.3	0.4
Myliobatidae		0.7	1.4	0.8	0.3
Nemipteridae	*Nemipterus japonicus*	1.8	1.0	5.9	4.5
Polynemidae					
	Eleutheronema tetradactylum	1.6	0.5	0.3	0.1
	Polynemus spp.	1.6	0.5	0.3	0.1
Rhinobatidae	*Rhynchobatus djiddensis*	0.1	0.2	0.1	0.1
Sciaenidae					
	Dendrophysa russelli	3.2	2.9	3.9	3.4
	Johnius belangerii	3.2	2.9	3.9	3.4
Scombridae					
	Rastrelliger kanagurta	18.3	12.7	8.0	9.3
	Scomberomorus commerson	0.6	0.6	0.7	0.9
	Scomberomorus guttatus	1.2	0.6	0.6	0.5
	Scomberomorus lineolatus	0.0	0.0	0.1	0.1
	Acanthocybium solandri	0.0	0.0	0.0	0.2
Serranidae					
	Epinephelus diacanthus	2.2	0.6	1.8	1.6
	Upeneus spp.	0.3	0.3	1.5	1.2
Sphyaenidae	*Sphyraena* spp.	0.1	0.1	0.5	0.9
Stromateidae	*Pampus* spp.	0.5	1.6	1.6	1.2
Stomatopoda		0.0	0.0	4.6	1.1

Table 4 continued. Percent composition of unreported artisanal catch from 1950-2010.

Family / Taxa		% Composition			
		1950	1970	1990	2010
Synodontidae					
	Harpadon nehereus	2.7	7.0	5.9	3.8
	Saurida spp.	0.1	0.5	1.7	2.0
Trichiuridae					
	Lepturacanthus savala	2.0	1.2	1.7	3.0
	Trichiurus lepturus	2.0	1.2	1.7	3.0
Miscellaneous sharks		2.0	2.9	1.9	0.9
Others[a]		1.2	0.4	0.8	1.1

[a.] The others category contains 'marine fishes nei' and an additional six taxa with minor contributions.

Table 5. Taxonomic composition of unreported molluscan catches (1950-2010).

Taxon		% composition		
		1950	1980	2010
Bivalves				
Arcidae	*Anadara granosa*	3.2	3.2	2.6
	Villorita cyprinoides	51.2	48.0	41.6
Veneridae	*Meretrix meretrix*	3.2	3.0	2.6
	Meretrix casta	10.4	9.8	8.5
	Katelysia opima	11.2	10.5	9.0
Others		0.8	0.8	0.7
Gastropods				
Trochidae	*Trochus radiatus*	20.0	25.0	35.0

Table 6. The percent species composition of shrimp trawl retained by-catch (East and West Coast) and discarded by-catch.

Taxon		By-catch (%)		Discards (%)
		West	East	
Apogonidae		0.1	0.1	3.0
Arcidae	*Anadara granosa*	0.1	0.1	1.0
Arridae	*Arius spp.*	1.5	1.0	2.5
	Tachysurus spp.	1.5	1.0	2.5
Brachyura	*Charybdis* spp.	0.1	0.1	2.0
	Portunus spp.	0.1	0.1	2.0
	Calappa lophos	0.1	0.1	2.0
Carangidae		1.0	2.0	5.0
	Parastromateus niger	5.0	3.0	1.0
Cephelapods	*Loligo* spp.	1.0	1.0	3.0
	Sepia spp.	1.0	1.0	3.0
Chirocentridae	*Chironcentrus dorab*	2.0	0.3	3.0
	Chironcentrus nudus	2.0	0.3	3.0
Clupeidae		2.5	2.5	6.0
Congridae	*Conger* spp.	3.0	3.0	0.5
Cynoglossidae	*Cynoglossus* spp.	0.1	0.1	2.0
Drepaneidae	*Drepane punctata*	3.0	3.0	1.0
Gerridae	*Gerres* spp.	3.0	4.0	0.1
Haemulidae	*Pomadasys argenteus*	3.0	4.0	0.1
Kurtidae	*Kurtus* spp.	3.0	4.0	0.1
Lactariidae	*Lactarius lacterius*	2.0	6.0	3.0
Leiognathidae	*Leignathus* spp.	2.0	6.0	4.0
	Gazza spp.	2.0	6.0	4.0
Lutjanidae	*Lutjanus* spp.	2.0	3.5	0.1
Mullusca	*Babylonia* spp.	0.2	0.3	1.0
	Turritella spp.	0.2	0.3	1.0
	Xancus pyrum	0.2	0.3	1.0
Muraenesocidae	*Muraenesox talabonoides*	3.0	2.0	1.0
	Muraenesox cinereus	3.0	2.0	1.0
Nemipteridae	*Nemipterus japonicus*	4.0	3.0	0.1
Palinuridae	*Panulirus polyphagus*	1.0	0.1	1.0
Penaeidae		2.0	1.5	0.3
Platycephalidae	*Platycephalus* spp.			3.0
Polynemidae	*Polynemus hepyadactylus*	2.0	2.0	3.0
	Polynemus indicus	2.0	2.0	3.0
Sciaenidae	*Pseudosciaena diacanthus*	5.0	3.0	3.0
	Otolithoides brunneus	5.0	3.0	2.0
	Johnius spp.	5.0	3.0	2.0
Sillaginidae	*Sillago* spp.	2.0	4.0	1.0
Soleidae		2.0	2.0	5.0
Sphyraenidae	*Sphyraena* spp.	1.0	1.0	0.5
Stomatopoda	*Oratosquilla nepa*	0.2	0.2	2.0
Stromateidae	*Pampus argenteus*	5.0	2.0	1.0
Synodontidae	*Saurida tumbil*	3.0	3.0	3.0
Terapontidae	*Terapon jarbua*	3.0	3.0	0.2
Tetraodontidae	*Lagocephalus* spp.	0.1	0.1	2.0
Trichiuridae		3.0	3.0	3.0
Sharks, rays and skates nei		5.0	5.0	5.0
Miscellaneous marine fish		2.0	2.0	2.0

Table 7. Major family groups for India's subsistence fishery.

Family	
Ambassidae	Megalopidae
Arcidae	Mugilidae
Ariidae	Muraenesocidae
Belonidae	Palaemonidae
Carangidae	Palinuridae
Centropomidae	Penaeidae
Chanidae	Plotosidae
Clupeidae	Polynemidae
Cynoglossidae	Portunidae
Decapoda	Sciaenidae
Engraulidae	Scorpaenidae
Ephippidae	Sergestidae
Gerreidae	Siganidae
Gobiidae	Sillaginidae
Haemulidae	Sparidae
Hemiramphidae	Sphyraenidae
Lactariidae	Terapontidae
Latidae	Tetraodontidae
Leiognathidae	Triacanthidae
Lutjanidae	Veneridae

Table 8. The percent composition of the inshore and offshore tuna unreported by-catch (Somvanshi *et al.* 1999).

Taxon	**West coast**		**East coast**	
	Inshore	**Offshore**	**Inshore**	**Offshore**
Acanthocybium solandri	0.4	0.5	0.4	0.5
Istiophorus platypterus	10.0	5.0	10.0	5.0
Istiompax indica	2.0	2.0	3.0	2.0
Scomberomorus commerson	58.0	47.0	30.0	21.0
Scomberomorus guttatus	20.0	15.0	51.0	43.0
Scomberomorus lineolatus	0.6	0.5	0.6	0.5
Xiphias gladius	4.0	2.0	0.1	
Sharks[a]	2.0	25.0	2.0	25.0
Others	3.0	3.0	3.0	3.0

[a.] For the species composition of shark by-catch see table 10.

Table 9. Percent breakdown applied to the FAO category 'sharks, ray, skates nei' from 1950-2010, based on Bhathal (2005). Values used were interpolated between decadal anchor points.

	% Composition			
FAO area 57	**1950**	**1970**	**1990**	**2010**
Rays	22	21	40	17
Sharks	75	76	56	75
Skates	3	3	4	8
FAO area 51				
Rays	65	71	63	47
Sharks	32	27	35	50
Skates	3	2	2	3

Table 10. Taxonomic composition of the reported shark catch and unreported shark by-catch for the west, east and outside Indian EEZ; derived from John and Varghese (2009).

Taxon		West Coast (%)	East Coast (%)	Outside EEZ (%)
Alopiidae				
	Alopias pelagicus	5.7	10.3	26.9
	Alopias superciliosus		4.2	0.6
	Alopias vulpinus	0.5	2.4	11.8
	Alopias spp.	0.3		
Carcharhinidae				
	Carcharhinus limbatus	26.7	17.0	5.8
	Carcharhinus macloti	1.0		0.1
	Carcharhinus sorrah	5.7		25.9
	Carcharhinus dussumieri	4.1		
	Carcharhinus melanopterus	8.2	47.3	0.6
	Carcharhinus falciformis	6.9		
	Carcharhinus albimarginatus	1.3	1.8	4.8
	Carcharhinus longimanus		0.6	4.7
	Carcharhinus spp.	1.8		
	Galeocerdo cuvier	1.0	1.2	4.0
	Lamiopsis temmincki	8.0		
	Prionace glauca	8.0		
	Rhizoprionodon acutus	8.0	3.0	3.0
Lamnidae	*Isurus oxyrinchus*	2.0	0.6	1.8
Sphynidae				
	Sphyrna lewini	0.3	6.1	
	Sphyrna zygaena	1.0	0.6	5.0
	Syphyrna mokarran	6.5		
Stegostomatidae	*Stegostoma fasciatum*		2.0	2.0
Other sharks		3.0	3.0	3.0

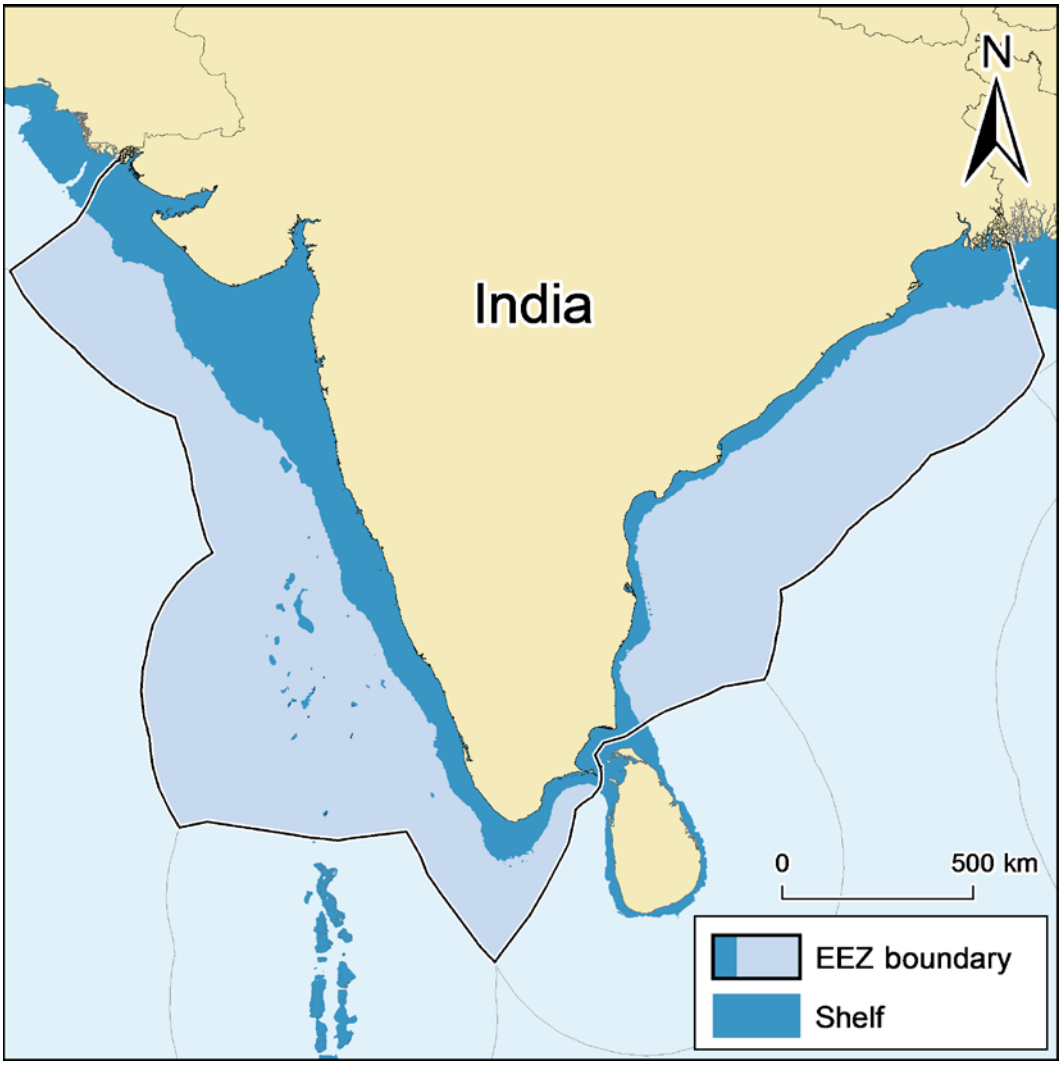

Figure 1. Exclusive Economic Zones (solid line) and coastal states and territories (numbered) of mainland India, and the Andaman and Nicobar Islands, which are covered elsewhere.

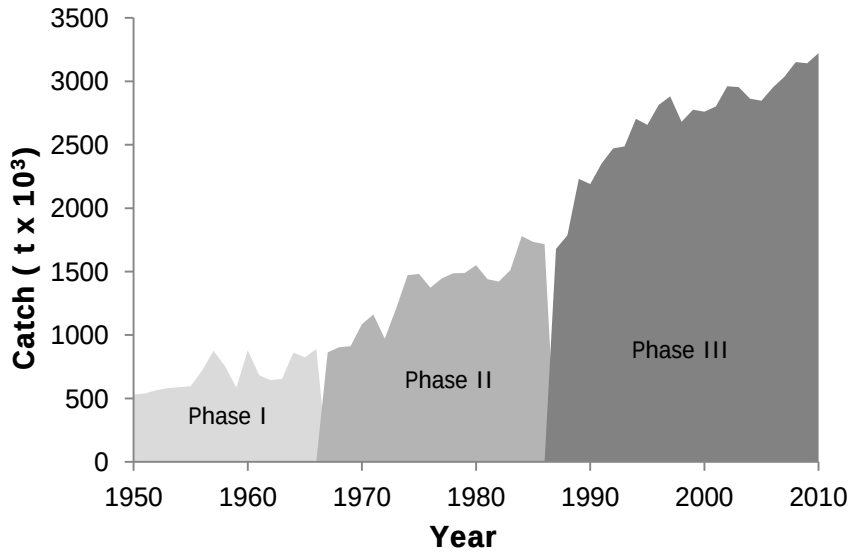

Figure 2. Three phases of development of Indian marine fisheries from 1950-2010. FAO catch data, as reported on behalf of India (fishstat database).

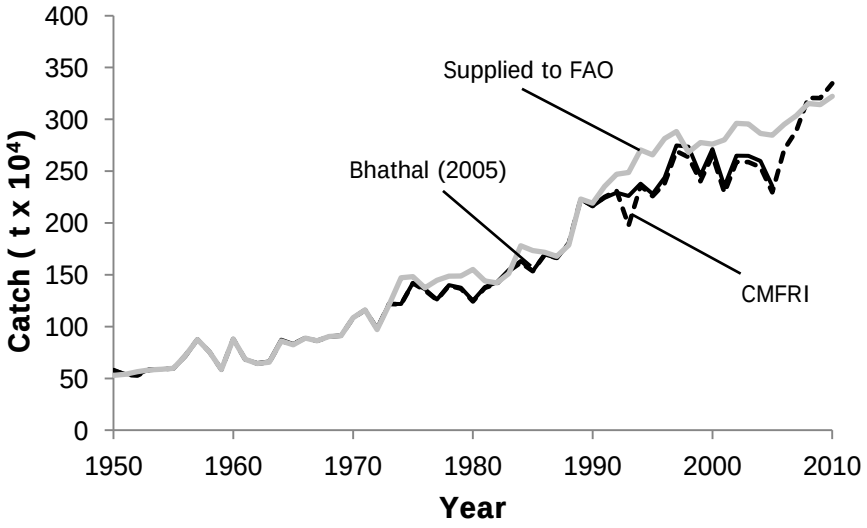

Figure 3. Comparison of India's official (FAO; green line) and national catch statistics (CMFRI; blue dashed line) from 1950-2010, with previously estimated marine catch (red line) from 1950-2005 (Bhathal 2005).

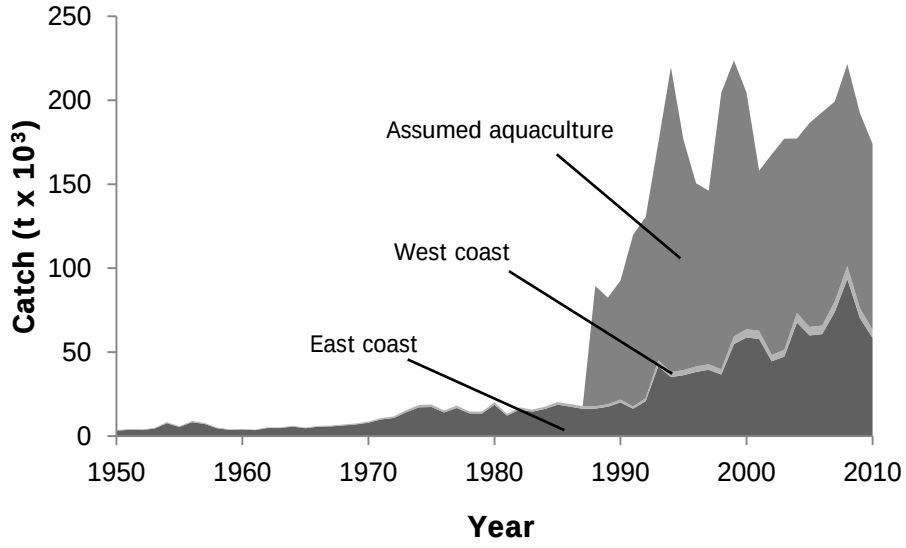

Figure 4. Catch of giant tiger prawn (*Penaeus monodon)* from the east and west coast of India. Aquaculture production was removed from the FAO data from 1988-2010.

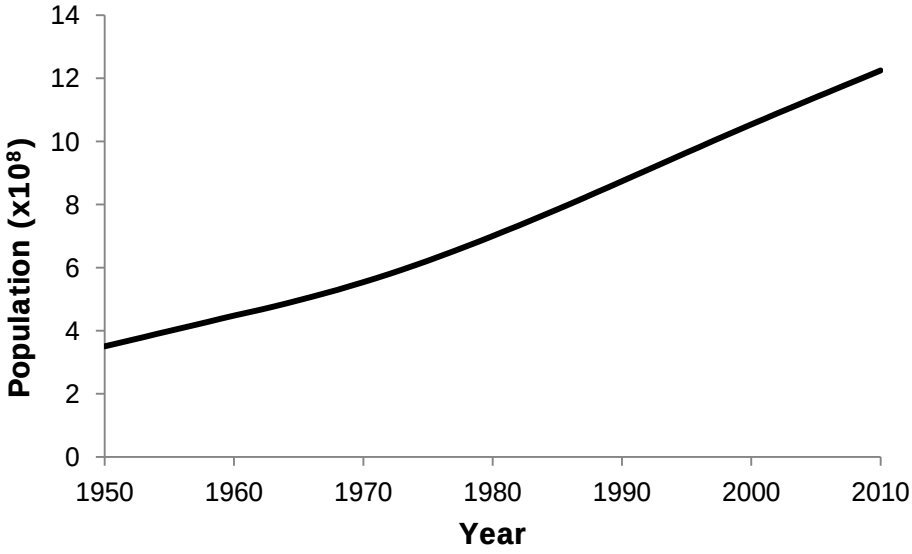

Figure 5. Human population data for mainland India, from 1950-2010.

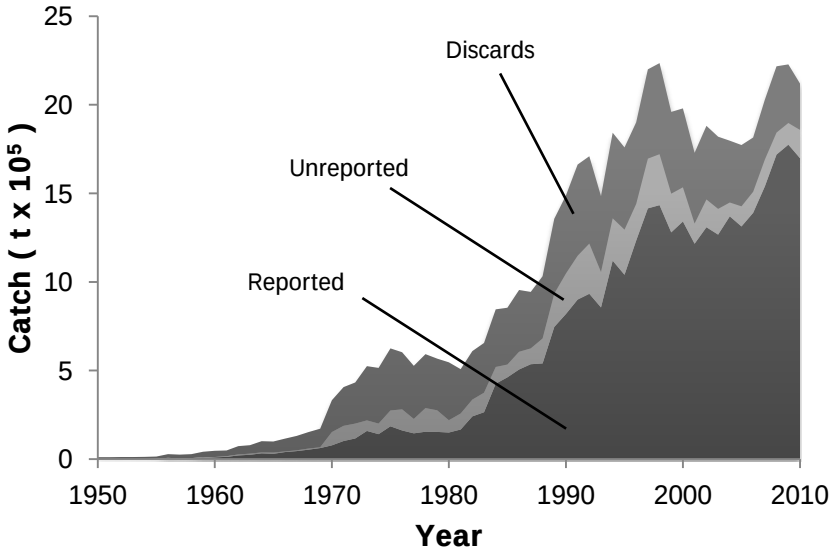

Figure 6. Total reconstructed industrial catch, showing reported and unreported catch, as well as discards from shrimp trawlers and other mechanized vessels from 1950-2010.

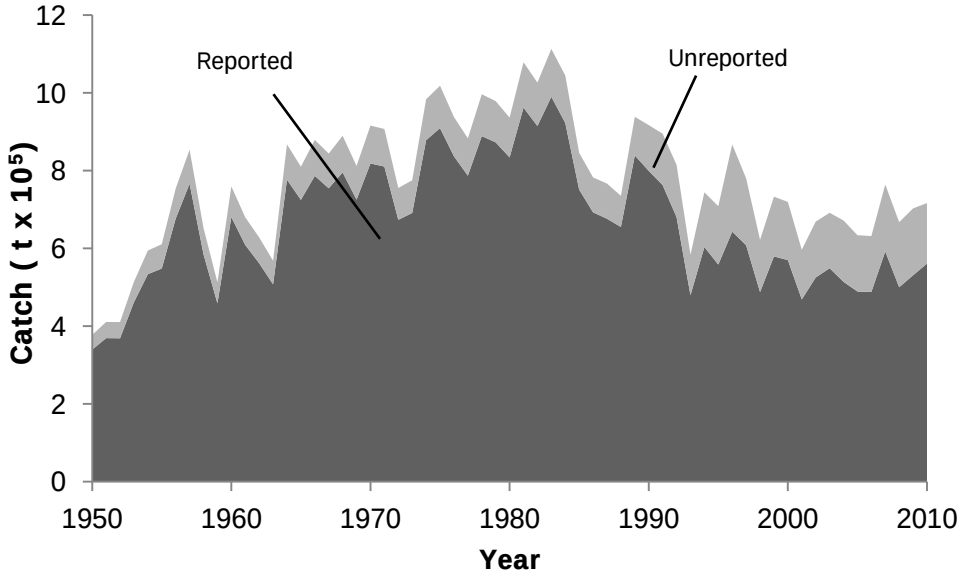

Figure 7. The reported and unreported catch from India's artisanal fishery from 1950-2010.

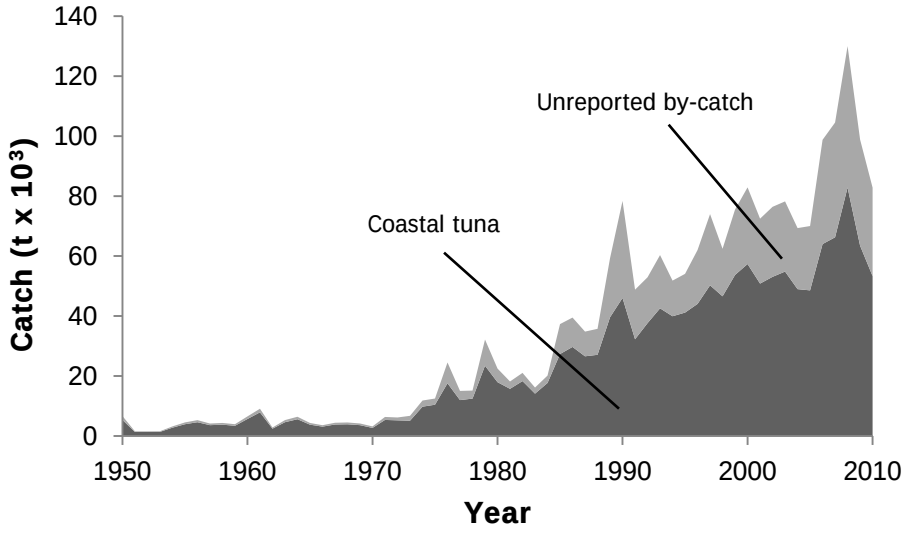

Figure 8. India's coastal tuna fishery with the reported and unreported by-catch of this fishery from 1950-2010.

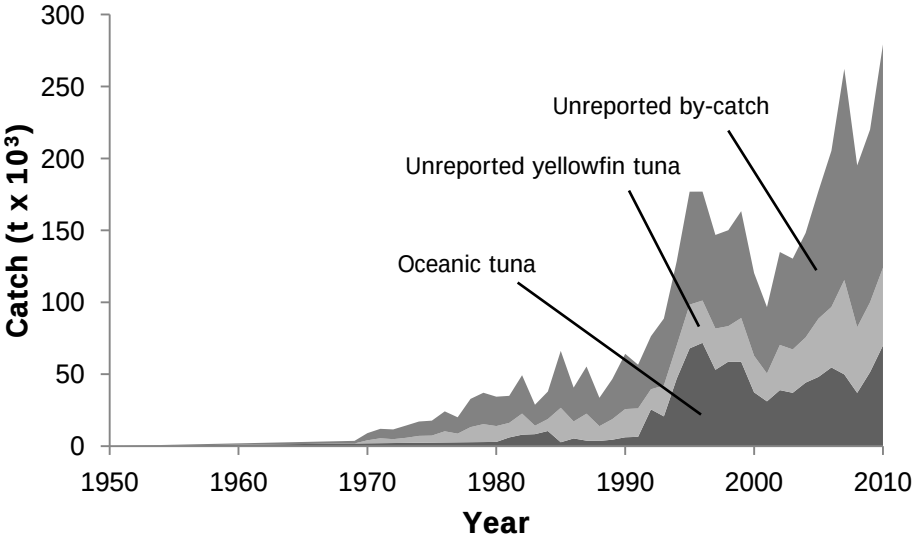

Figure 9. Total catch by the oceanic tuna fishery (including catch by LoP industrial tuna vessels), the unreported catch of yellowfin tuna (*Thunnus albacares*) and unreported by-catch from 1950-2010.

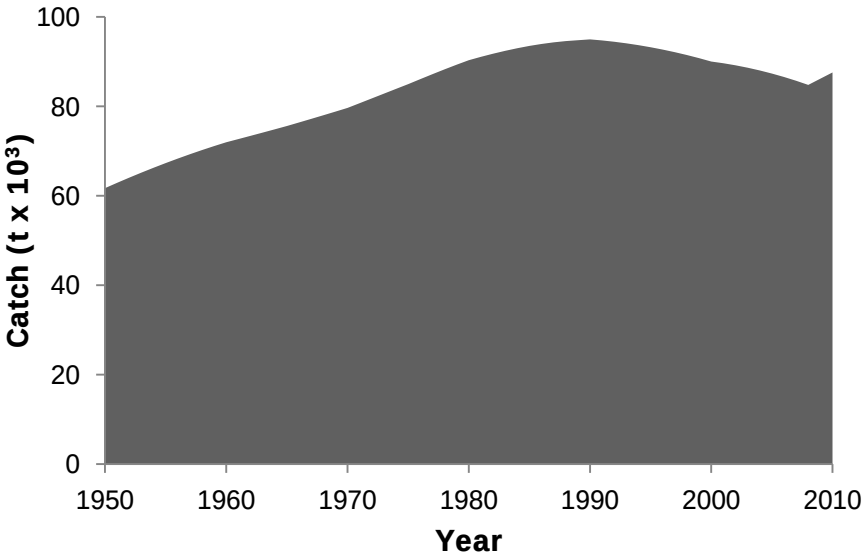

Figure 10. Reconstructed subsistence catch from India during the period 1950-2010.

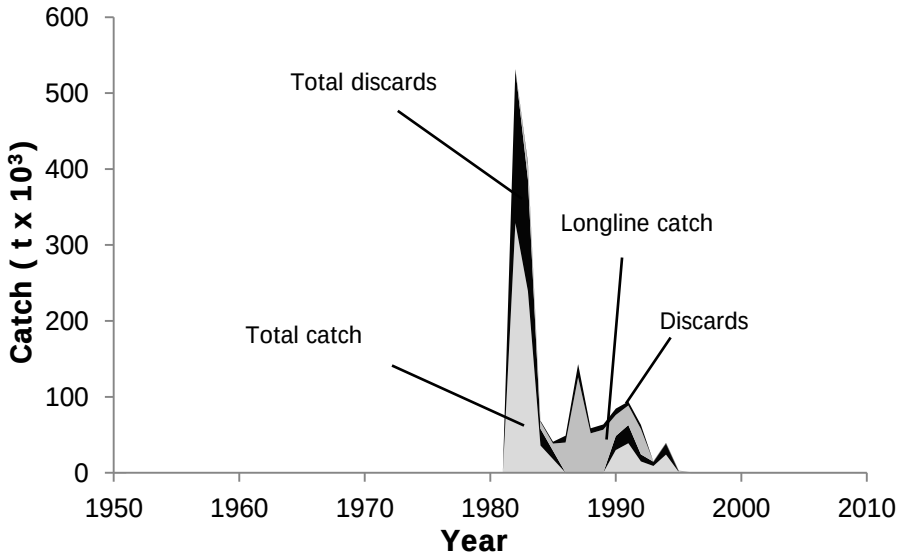

Figure 11. Catches by foreign chartered trawlers (blue), along with discards (red), operating from 1983-1985 and 1990-1995. Catch (green) and discarded by-catch (purple) of chartered longliners from 1985-1995.

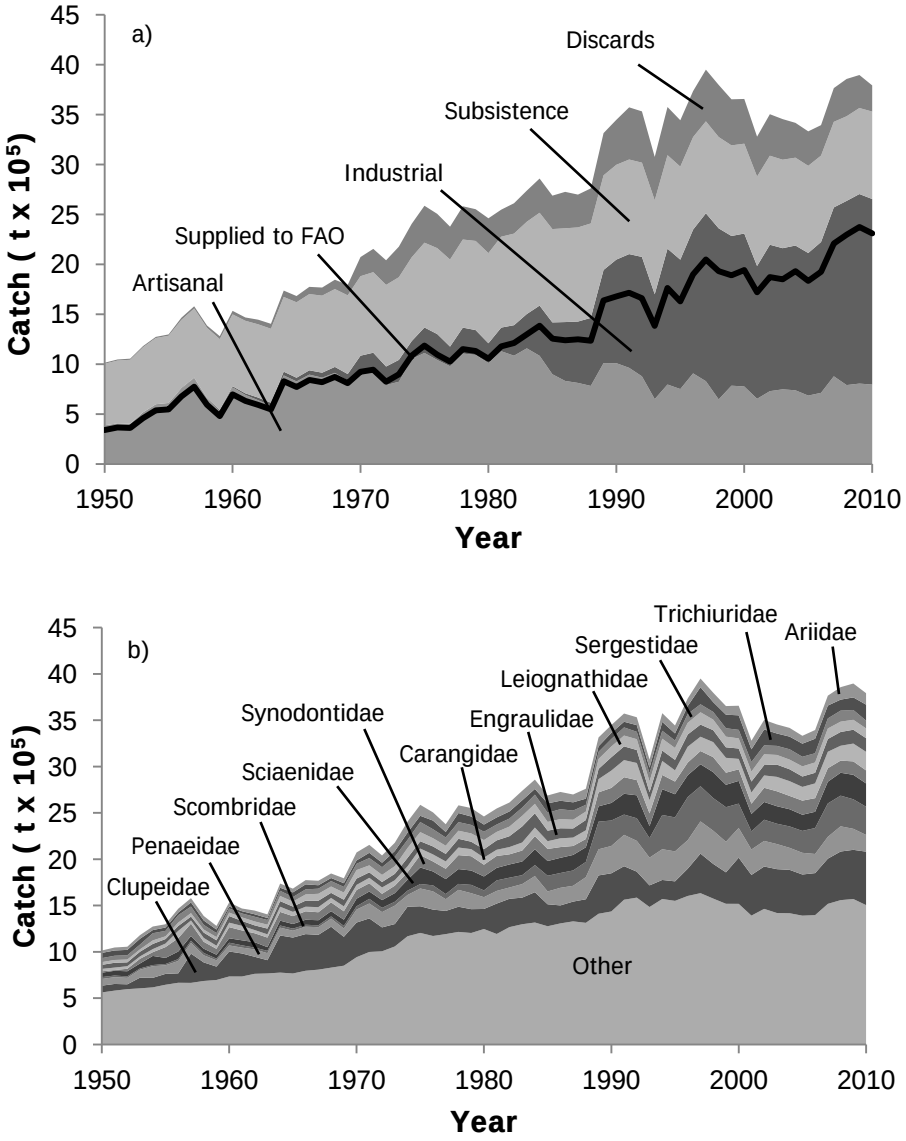

Figure 12. Total reconstructed catches for India's marine fisheries (excluding the Andaman and Nicobar Islands), from 1950-2010, a) by sector, with officially reported FAO data overlaid as line graph. Note the FAO data has been adjusted to exclude aquaculture production; and b) by major taxa, with the 'other taxa' category consisting of 63 additional families and a 'marine fishes nei' category.

Appendix Table A1. FAO landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately, for India within its EEZ, 1950-2010.

Year	FAO landings	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discards
1950	340,052	1,015,000	4	386,900	617,000	10,600
1951	365,157	1,047,000	99	406,900	629,000	10,800
1952	360,283	1,055,000	294	403,000	640,000	11,300
1953	458,717	1,181,000	343	517,100	652,000	11,700
1954	537,233	1,289,000	527	614,200	663,000	11,900
1955	547,098	1,298,000	1,732	610,200	673,000	12,800
1956	676,443	1,465,000	7,398	753,700	683,000	20,900
1957	773,631	1,587,000	3,424	868,300	693,000	22,200
1958	592,785	1,403,000	5,344	672,800	702,000	23,100
1959	479,458	1,288,000	12,260	535,000	711,000	29,500
1960	697,737	1,549,000	11,806	782,600	720,000	35,200
1961	631,762	1,468,000	15,898	691,800	727,000	33,300
1962	592,279	1,445,000	26,624	638,500	734,000	46,400
1963	546,725	1,404,000	30,915	583,900	741,000	48,000
1964	828,318	1,737,000	37,966	887,300	749,000	63,200
1965	771,507	1,682,000	37,392	827,100	756,000	61,900
1966	842,197	1,774,000	43,009	895,200	764,000	72,300
1967	819,516	1,767,000	50,064	864,600	772,000	81,000
1968	871,852	1,846,000	59,964	912,900	780,000	93,100
1969	809,670	1,794,000	67,326	834,600	788,000	103,900
1970	923,479	2,073,000	152,480	944,100	796,000	180,200
1971	945,020	2,155,000	188,020	941,000	807,000	218,800
1972	824,699	2,041,000	200,512	790,500	818,000	231,900
1973	897,435	2,183,000	218,844	830,200	828,000	306,200
1974	1,085,522	2,405,000	200,293	1,051,500	839,000	314,300
1975	1,186,097	2,587,000	274,382	1,112,100	850,000	350,700
1976	1,095,307	2,506,000	280,499	1,041,500	861,000	322,800
1977	1,025,657	2,377,000	226,899	979,100	872,000	299,400
1978	1,150,851	2,582,000	287,710	1,106,200	883,000	305,000
1979	1,131,057	2,552,000	275,561	1,092,000	893,000	291,600
1980	1,054,671	2,461,000	219,136	1,011,400	903,000	327,500
1981	1,177,634	2,548,000	257,348	1,129,300	911,000	250,300
1982	1,211,204	2,613,000	335,720	1,084,700	918,000	273,700
1983	1,298,380	2,740,000	374,951	1,158,400	924,000	280,900
1984	1,384,770	2,863,000	520,059	1,083,800	930,000	325,600
1985	1,255,558	2,689,000	534,220	898,700	935,000	320,000
1986	1,239,010	2,727,000	606,613	831,800	939,000	348,200
1987	1,249,063	2,701,000	625,513	812,000	943,000	318,100
1988	1,233,839	2,760,000	681,485	782,100	946,000	351,100
1989	1,637,600	3,315,000	934,051	1,010,300	948,000	422,500
1990	1,678,770	3,448,000	1,047,203	1,009,700	950,000	441,100
1991	1,715,069	3,574,000	1,147,751	963,100	947,000	514,400
1992	1,661,408	3,534,000	1,216,527	878,100	944,000	493,300
1993	1,383,954	3,075,000	1,056,281	649,800	941,000	428,100
1994	1,763,321	3,575,000	1,359,722	796,000	937,000	482,400
1995	1,627,862	3,443,000	1,295,051	750,600	932,000	464,400
1996	1,899,197	3,747,000	1,440,505	907,500	927,000	460,600
1997	2,048,755	3,953,000	1,696,402	829,300	921,000	503,600
1998	1,931,330	3,797,000	1,722,184	646,800	915,000	513,500
1999	1,889,854	3,653,000	1,499,525	784,400	908,000	461,500
2000	1,943,560	3,657,000	1,535,094	776,300	900,000	445,200
2001	1,720,626	3,278,000	1,330,229	652,900	896,000	399,600
2002	1,872,498	3,503,000	1,466,762	729,500	892,000	415,900
2003	1,849,836	3,453,000	1,413,916	747,800	886,000	406,700
2004	1,932,296	3,421,000	1,450,819	738,100	880,000	348,700
2005	1,769,175	3,335,000	1,366,382	685,000	873,000	345,400
2006	1,860,382	3,393,000	1,448,202	712,700	866,000	305,400
2007	2,129,051	3,764,000	1,615,395	878,400	857,000	338,100
2008	2,195,018	3,855,000	1,747,875	790,400	848,000	373,700
2009	2,298,333	3,900,000	1,826,320	805,300	862,000	330,500
2010	2,247,594	3,793,000	1,798,706	795,400	876,000	262,300

Appendix Table A2: Total reconstructed catch (tonnes) for India (1950-2010) by major taxa. 'Others' category includes 'marine fishes nei' and 63 additional taxa.

Year	Clupeidae	Penaeidae	Scombridae	Sciaenidae	Synodontidae	Carangidae	Engraulidae	Leiognathidae	Sergestidae	Trichiuridae	Ariidae	Others
1950	73,137	72,048	20,479	47,259	15,324	25,850	43,704	29,538	42,808	56,599	25,851	561,769
1951	72,018	72,908	17,839	51,321	7,927	26,702	51,905	30,160	45,813	56,736	32,158	581,235
1952	52,302	70,227	15,574	55,075	26,989	27,511	41,765	30,412	45,812	58,345	34,008	597,076
1953	115,436	85,854	13,667	54,005	50,413	25,710	50,549	25,566	51,915	62,404	39,397	605,876
1954	102,973	125,543	12,673	98,405	40,295	33,147	55,641	38,181	77,581	34,048	38,462	616,307
1955	117,392	92,494	13,833	65,852	116,975	38,189	48,525	29,634	58,792	36,238	35,162	644,699
1956	101,636	133,555	20,194	81,870	144,382	78,525	52,895	36,668	80,107	27,918	41,276	666,132
1957	315,731	115,519	23,505	51,505	133,390	33,841	42,188	37,285	71,036	44,586	46,088	664,902
1958	200,465	77,058	24,795	46,277	74,440	41,769	57,537	32,505	50,928	47,440	48,519	685,398
1959	144,582	67,697	17,735	42,889	63,542	33,596	58,484	34,648	43,241	38,228	39,385	696,082
1960	269,536	65,232	29,622	47,381	120,384	48,371	71,173	37,656	44,483	21,543	44,427	734,169
1961	248,585	63,150	24,991	53,915	106,634	49,508	53,107	37,945	42,549	24,182	29,305	733,787
1962	183,987	79,531	19,213	58,620	96,526	34,364	50,685	42,248	50,894	26,557	40,087	762,725
1963	143,212	75,681	25,038	39,951	103,494	34,956	61,986	42,161	50,425	22,052	38,420	766,685
1964	400,647	84,279	23,517	52,291	94,429	55,869	60,466	55,533	55,922	33,054	45,180	775,813
1965	387,698	74,029	22,392	50,068	84,903	45,963	57,294	53,606	49,023	50,323	40,762	766,325
1966	395,619	80,030	20,936	53,987	91,101	49,684	65,611	66,935	54,653	54,285	45,735	795,724
1967	375,717	82,455	20,708	54,431	86,244	55,366	69,256	74,767	55,204	36,996	48,506	807,684
1968	441,679	87,298	24,051	56,625	94,689	47,555	55,373	68,418	58,638	33,219	48,922	829,398
1969	311,717	89,146	28,519	66,994	91,010	52,898	71,918	77,213	61,350	39,680	52,995	850,538
1970	374,055	140,181	35,247	82,158	94,103	54,613	68,495	91,669	67,785	36,423	86,066	942,190
1971	362,156	160,845	50,364	79,302	88,478	59,097	58,813	75,798	78,867	56,798	85,647	998,568
1972	258,153	164,902	45,637	83,849	68,093	68,374	58,953	76,642	83,459	48,359	78,344	1,005,772
1973	241,772	198,731	42,037	93,045	80,307	58,978	68,871	82,913	101,263	62,211	89,106	1,057,929
1974	319,366	126,306	46,554	118,292	80,146	64,132	91,403	106,055	88,195	78,579	118,174	1,167,917
1975	287,650	191,939	48,009	178,803	133,974	70,215	78,691	98,679	108,678	67,572	118,239	1,204,322
1976	284,903	196,624	65,309	149,738	107,813	76,063	86,189	88,650	97,213	93,378	88,583	1,171,051
1977	250,040	126,755	55,292	162,050	111,247	78,887	81,641	88,021	89,090	59,386	83,419	1,191,406
1978	271,675	181,900	64,458	160,032	150,752	82,075	93,754	87,495	93,018	97,808	83,372	1,215,209
1979	257,057	172,409	89,931	154,927	154,472	76,197	80,179	89,343	92,143	90,617	91,435	1,203,518
1980	216,469	127,266	73,040	150,552	126,918	76,419	91,076	98,489	89,934	77,411	87,249	1,246,292
1981	328,257	136,629	113,615	135,147	128,731	66,928	101,415	91,109	79,832	76,488	96,682	1,192,732
1982	305,809	121,787	106,041	142,827	109,212	78,598	117,209	103,586	86,775	76,664	96,526	1,266,712
1983	287,199	145,987	96,236	147,539	118,346	86,914	173,302	114,184	88,915	79,011	102,630	1,297,958
1984	327,208	174,290	118,301	170,179	142,143	92,614	153,782	102,566	99,029	62,112	100,499	1,316,560
1985	236,948	138,429	169,655	159,026	130,390	83,615	113,695	94,276	98,058	102,336	85,311	1,276,247
1986	194,311	189,922	159,818	163,944	115,932	94,488	108,707	98,868	106,792	91,335	95,006	1,306,879
1987	213,307	170,587	165,558	167,722	96,521	90,775	98,414	94,149	98,946	89,002	84,713	1,328,908
1988	254,548	238,300	164,621	158,266	88,965	94,303	110,843	91,480	72,615	66,493	107,072	1,313,013
1989	413,801	282,099	298,221	165,694	150,766	142,715	110,615	107,246	76,609	60,591	95,136	1,411,148
1990	411,911	294,980	274,912	189,589	162,278	187,036	143,889	116,194	80,852	65,908	84,383	1,435,762
1991	361,962	338,240	218,820	224,689	178,773	184,742	148,032	116,887	87,864	61,035	88,946	1,562,546
1992	280,331	332,445	243,749	247,859	163,908	185,005	140,163	116,742	79,634	72,114	84,978	1,585,286
1993	233,543	299,148	210,511	130,943	137,041	141,958	86,452	116,720	87,066	60,175	88,455	1,483,909
1994	205,253	331,957	369,677	277,564	154,253	151,125	112,110	128,148	85,452	96,108	93,747	1,570,590
1995	210,581	323,705	366,622	250,257	136,920	120,852	113,355	128,252	80,501	76,604	85,377	1,550,193
1996	294,364	307,245	465,941	236,292	136,408	170,777	132,495	125,403	95,636	86,000	81,586	1,603,305
1997	426,843	347,645	379,747	237,158	142,869	154,408	130,969	133,236	86,018	184,679	93,312	1,633,419
1998	374,439	358,178	351,985	280,233	161,903	162,299	128,672	113,739	83,139	105,960	101,677	1,574,930
1999	339,580	330,043	373,158	241,932	130,687	160,264	113,615	114,970	90,754	146,325	93,172	1,518,590
2000	498,480	320,364	263,167	245,262	124,707	112,591	112,112	109,401	92,108	156,739	103,684	1,518,082
2001	439,148	274,250	195,891	188,173	110,543	120,927	118,211	107,862	103,247	136,685	92,909	1,391,166
2002	457,243	276,272	228,836	191,611	153,172	133,276	112,316	116,348	96,047	171,791	103,222	1,463,721

Appendix Table A2: Total reconstructed catch (tonnes) for India (1950-2010) by major taxa. 'Others' category includes 'marine fishes nei' and 63 additional taxa.

Year	Clupeidae	Penaeidae	Scombridae	Sciaenidae	Synodontidae	Carangidae	Engraulidae	Leiognathidae	Sergestidae	Trichiuridae	Ariidae	Others
2003	473,362	270,792	219,597	188,926	161,560	155,307	132,315	104,392	97,845	133,753	97,773	1,419,114
2004	468,325	237,674	231,265	185,374	143,816	159,336	128,238	104,362	111,692	136,596	94,048	1,416,474
2005	444,347	234,033	236,531	174,483	152,535	147,888	112,296	109,405	103,601	141,694	84,750	1,390,478
2006	453,555	206,495	279,984	175,485	147,042	159,473	114,289	112,055	99,311	156,266	94,306	1,396,285
2007	488,095	235,362	360,623	234,421	146,021	177,546	137,773	113,243	108,827	138,715	106,937	1,517,874
2008	524,828	272,147	330,940	247,216	130,968	160,646	148,448	111,485	119,036	118,669	134,710	1,557,993
2009	530,985	226,866	318,689	264,209	145,074	192,153	149,325	107,297	105,867	135,917	149,986	1,570,133
2010	576,981	180,624	303,921	252,141	140,536	200,244	147,471	105,494	84,090	172,608	123,692	1,504,537