I. INTRODUCTION

Fishing is one of the ancient occupations and recognized as a main source of income and employment generation to large sections of the society. It has got a significant role in the economic and social wellbeing of millions of people worldwide. Apart from this, it provides a cheap source of animal protein to the people, especially for the poorer sections in the society, thereby it serves as a means to ensure the food security for millions of people, and contributing about 17% of animal protein supply (Anon, 2014). All over the world about 200 million people are directly or indirectly dependent on the fisheries industry. Of this about 50 million people directly depend on fishing for their livelihood and the remaining involved in allied activities such as processing, marketing, and supporting activities (Anon, 1995).

According to FAO the total world fish production was 158 mt in 2012, out of which marine capture fisheries contributed about 79.2 mt (87.2% to the world capture fisheries). A total 21.7 mt from the world fish production were considered as non-food purpose (Anon, 2014). The annual growth rate reduced from 6% during 1950-1970 to almost zero after 1990, since most of the fish stocks have apparently reached their maximum sustainable level of exploitation. It is important to note that in year 2009, about 57.4% of the world fish stocks were fully exploited, 29.9% over-exploited, and only 12.7% were left at levels not reaching full exploitation (Anon, 2011a).

Trawling, though one of the most efficient methods of catching fish world over, is also the most important human caused physical disturbance to the world’s continental shelves, and consequently, the physical destruction of marine ecosystems (Jennings and Kaiser, 1998). Trawls are mainly operated from surface to bottom that targeted at specific
groups of organisms, and trawl net being a non-selective gear, catches everything available in its towing path. In general non-targeted, non-commercial species in the by-catch get thrown overboard, a practice called discarding (Van Beek, 1998).

Bottom trawling is known to be the most effective method for shrimp capture and is widely accepted in the world. Intensity of trawling has a vicious impact on benthic ecology and biodiversity (Dayton et al., 1995). Incidental catching of non-target resources has become serious problem faced by trawl fisheries in the world. Some part of the non-target catch may be retained for sale or use, while others being discarded back into the sea due to number of reasons like fish of wrong species, size, sex, damaged, lack of space for storage, prohibited species, etc. (Clucas, 1997). The biological and economic loss due to discarding is one of the important issues that has to be tackled by the fishery managers (Kelleher, 2005).

**Marine Fisheries of India**

India is endowed with a long coastline of 8,129 km with an exclusive economic zone of 2.02 million km² and a continental shelf area of 0.5 million km². Marine fish production of India was only 0.5 mt in 1950s and that has increased to 3.07 mt in 2010 (Ayyappan et al., 2011). About 58% of the fisheries resource is available at a depth of 0-50 m, 35% at 50-200 m and 7% from beyond 200 m depth. The present catch is largely derived from the intensively fished shelf waters. According to a CMFRI census 2010 about 1,94,490 fishing crafts of various sizes and classes consisting of 72,559 mechanised (37.3%), 71,313 motorised (36.7%) and 50,618 non-mechanised (26%) fishing vessels operate in the maritime India (Anon, 2010a). The mechanized sector contributed 73%, motorized 25% and artisanal 2% of the total fish landings (Anon, 2011b).
The first trawling attempt in Indian waters was by the mechanized vessel *S.T. Premier* in 1900 off Bombay coast (Chidambaram, 1952; Mukundan and Hameed, 1993) and by the Ceylon Company for Pearl Fishing Survey (Hornell, 1916). According to Gnanadoss (1977) only 13 mechanised fishing vessels were in operation in 1947. Pair trawling operation was carried out from Japanese Trawler *Taiyo Maru-17*, during 1947 (Chidambaram, 1952).

The number of trawlers operating in Indian waters has been recently estimated at 35,228 with maximum number operating in Gujarat (32.8%), followed by Tamil Nadu (16.3%), Maharashtra (16%), Kerala (10.5%), Karnataka (8.1%), Andhra Pradesh (3.8%), West Bengal (3.8%), Orissa (3.7%), Goa (2.5%), Daman & Diu (1.5%) and Pondicherry (1%). Of the total trawler fleet in India, 71.4% operates in the west coast and 28.6% in the east coast (Anon, 2010a).

According to the recent estimates by CMFRI, the marine fish landings of India during 2012 have registered an all time high of 3.93 mt, compared to 3.82 mt during 2011 showing 3.4% growth. Kerala State was the highest contributor towards production with 8.5 lakh t. All maritime states and union territories except West Bengal and Odisha showed an increase in production during 2012-2013. Southwest region comprising Kerala, Karnataka and Goa contributed maximum to the region-wise landings with 13.9 lakh t (35.1%) followed by northwest region with 11.5 lakh t (29.2%), southeast region 10.1 lakh t (25.5%) and northeast 4 lakh t (10.2%). The pelagic fishes constituted 54%, demersal fishes 28%, crustaceans 13% and molluscs 5% of the total landings. While considering the sector-wise contribution of marine fish landings during the year 2012-2013, the mechanized sector accounted for 78%, motorized sector 20% and artisanal sector 2% of total production (Anon, 2013).
Karnataka has a 300 km coastline with continental shelf of 27,000 km². Trawlers (78%), purse-seiners (12%) and gillnetters (5%) are mainly contributing to the fish production from the state’s mechanised sector. There are about 96 fish landing centres in the state. Mangalore in Dakshina Kannada, Malpe in Udupi and Karwar in Uttara Kannada are main landing centres. Mangalore fishing harbour is one of the important landing centres of Karnataka Coast, contributing more than 40 percent of the total catch of Karnataka (Anon, 2010b).

In Karnataka, bottom trawling was first introduced by the Japanese trawler M.S. Kaiko Maru in 1961. During 1963-67, vessels of the Indo-Norwegian Project conducted systematic exploitation of fishing grounds. Initially trawlers operated 10-15 km offshore, but later shifted to shallow waters which promised good catch (Kurup et al., 1987). The target species of trawlers in Karnataka were high valued prawns, squids, cuttlefishes, threadfin breams and ribbonfishes (Dineshbabu et al., 2012).

The marine fish production during 2011-12 was estimated 3.47 lakh t in Karnataka. Presently, 269 purse-seiners, 4,626 gillnetters (OBM), 355 Inboard gillnetters, 1,740 trawlers, 1,122 multiday trawlers, 138 longliners, 50 other mechanized boats and 5,551 traditional crafts are operating along the coast (Anon., 2012a). The pelagic fishes dominated the fishery which contributed (54.3%), followed by demersal fishes (25.5%) crustaceans (9.4%), molluscs (8.0%) and others (2.8%) of the total landings in Karnataka. The mechanized sector contributed 73%, motorized 25% and artisanal 2% of the catch during 2010-2011 (Anon, 2011b).

The trawl landings along the Indian coast generally consist of 76% demersal groups, which include demersal finfish (38%) and invertebrates (38%). The remaining
24% are pelagic and column-water fishes (Ayyappan et al., 2011). Consequent upon increase in the number and efficiency of trawlers, the demersal landings have increased during the last 40 years. However, the indiscriminate trawling in the last one decade has affected the bottom habitat and the demersal resources as well. Now there are evidences of decline in the stocks of few demersal groups and shift in the composition of the landings.

**Bycatch in Fisheries**

As per the United Nations Convention on the Law of the Sea held in 1982, the rights and responsibilities for the management of the resources within the EEZ are vested with the coastal states. In shrimp-trawl fisheries bycatch may be defined as anything the fisherman does not intend to catch and include turtles, fish, crabs, sharks, stingrays, pieces of corals, weeds and seafed debris. Sometimes this is called incidental or accidental catch.

Bycatch and discards are the common problems faced by all fishers globally and it is a major component of the negative impacts of fishing on marine ecosystems. It is an extremely complex set of scientific and ecosystem-wide issue and includes many economic, political and moral factors. Bycatch is recognized as unavoidable in any kind of fishing but the quantity varies according to the gear operated (Riedel and Dealteris, 1995; Pillai, 1998; Hall et al., 2000; Matsushita, 2000; Ortiz et al., 2000; Costa et al., 2001; Madsen and Hanson, 2001; Chuenpagdee et al., 2003; Morgan and Chuenpagdee, 2003; Sandra, 2003; Lewison et al., 2004; Fonseca et al., 2005; Harrington et al., 2006; Pierre and Norden, 2006; Eayrs, 2007).

Bycatch was closely associated with fishing from the very beginning of the commercial fishing operations and it presented some unique problems to the fishery
managers. The changing perspective of bycatch itself offers the greatest challenge, as yesterday’s bycatch becomes today’s target catch (Boyce, 1996).

**Bycatch Definitions**

There are a number of definitions available regarding the term, bycatch. Gordon (1991) defined bycatch as “non-target species caught with and incidentally to the target species”. McCaughran (1992) defined bycatch as ‘that portion of the catch returned to the sea as a result of economic, legal or personal considerations plus the retained catch of non-targeted species’. Hall (1996) defined bycatch as “that part of the catch that is discarded at sea dead (or injured to an extent that death is the result)”. Clucas (1997) defined bycatch as “that part of the catch which is not the primary target of the fishing effort which includes fish which is retained, marketed (incidental catch) and that which is discarded or released”. Pillai (1998) defined the term bycatch as “the portion of catch other than the target species caught while fishing for a particular species”. Hameed and Boopendranath (2000) stated that “bycatch includes undersized fish, non-targeted fish species, birds, mammals and other organisms encountered during fishing operations”.

Alverson et al. (1994) concluded that there are mainly three accepted definitions of bycatch. In some areas, bycatch is the catch, which is retained and sold, that is not target species. In some other areas, bycatch means species or sizes and sexes of fish which are discarded. The term bycatch is also known to include all non-target fish species retained, sold or discarded. Bycatch may include individuals of target species smaller than the legal minimum landing size, juveniles of commercial and/or recreational fisheries species, or individuals of threatened, endangered or protected species (Kennelly, 1995; Lewison et al., 2004). Boopendranath (2007) has discussed the terminologies used such as gross catch, bycatch, discarded bycatch and retained bycatch.
Eayrs (2007) stated that bycatch includes all non target animals and non-living material (debris) which are caught while fishing. In shrimp-trawl fisheries bycatch may be defined as anything the fisherman does not intend to catch and may include turtles, fish, crabs, sharks, stingrays, pieces of coral, weed and seabed debris. Sometimes this is called incidental or accidental catch. Discards are that part of the bycatch that are released or returned to the sea either dead or alive. It also includes all animals and non-living material that interact with the fishing gear but do not reach the deck of the boat. The discarded catch may consist of species of low commercial value, undersized commercially important species, juveniles and seabed debris. The term trash fish usually applies to small, undersized fish and other animals that were traditionally discarded overboard because they had no economic value. However, in recent years this part of the catch has become a substantial source of income for many small-scale fishermen because it can be sold as fish meal or food for cultured fish or shrimp.

Costa et al. (2008) also illustratively classified these terminologies to avoid further confusion given terms and definitions: total catch is the quantity of all species brought onboard; target catch is the fraction of the total catch which includes the species towards which the fishing effort is directed (target species); retained (or landed) catch is the part of the total catch that has economic value (i.e. the quantity of target and bycatch species that can be marketed); and total bycatch is the portion of the total catch which includes all the species caught accidentally (non target species). Total bycatch may be retained if it has commercial value (commercial bycatch) and/or discarded at sea if it is not used for any purpose (discarded bycatch). In order to simplify, “discarded bycatch” is referred to as “discard(s)”. 
Terminologies used

**Bycatch**

“Total fishing mortality excluding that accounted directly by the retained catch of target species” or “It is the unintended catch taken while targeting a particular species”. or “It is the catch that is either unused or unmanaged” (Kelleher, 2005).

**Discard**

“Discards are that portion of the total catch which is dumped or thrown overboard at sea” (Kelleher, 2005). Discards are generally considered a waste of fish resources and inconsistent with responsible fisheries.

In general: Non-targeted, non-commercial species in the bycatch will be thrown overboard, a practice called discarding. Not only include non-commercial species, but several other commercial species that are below minimum legal size (MLS) or are less profitable owing to market conditions (Anon, 2011b). A major quantity of the juvenile fishes is caught as ‘bycatch’.

**Low Value Fish (LVF)**

The use of the term “L V F” varies from country to country. One category of LVF is those not used for direct human consumption, which may be either landed or discarded at the sea itself. The small cod end mesh of bottom trawlers also exploits juveniles.

**Trash Fish**

“Fish that have a low commercial value by virtue of their low quality, small size or low consumer preference or used for livestock/fish, either directly or through reduction to fish meal/oil (Anon, 2005a). The term “low-value fish” is preferred to “trash fish” (Anon, 2012b).
Trash fishes not only include non-commercial species, but also commercial species that are below minimum legal size (MLS) or less profitable species owing to market conditions (Catchpole et al., 2005).

**Juvenile**

The definition, “juveniles are young fish, mostly similar in form to adult but not yet sexually mature” by Hubbs (1943). A juvenile is an individual organism that has not yet reached its adult form, sexual maturity or size. This holds appropriate criteria for distinguishing juveniles of tropical fishes and it is used in the present study.

A perusal of literature revealed that there is need of regular assessment of by-catch and discards associated with bottom trawling to understand the extent of resource damage due to indiscriminate fishing and loss of commercially important juveniles. Hence, the present study is taken up along Mangalore coast with the following objectives-

**Objectives**

I. Quantification of trash fish landing in single day and multiday trawlers at Mangalore Fisheries harbor.

II. To identify the finfish species in trash fish and their catch composition, landed by trawlers.

III. To find out percentage of juveniles of commercially important finfish species in trash fish.

IV. To study the impact of the landing of commercially important finfish juveniles in trash fish in marine fisheries of Karnataka.
II. REVIEW OF LITERATURE

Commercial fishing is one of the most serious threats to the world’s remaining fish stocks (Pauly et al., 2002; Worm et al., 2006) especially the indiscriminate capture (Kumar and Deepthi, 2006) of non-target organisms, typically referred to as ‘bycatch’. Bycatch may be sold or it may also be unwanted for a variety of regulatory and economic reasons and subsequently thrown back to sea, often dead or dying (Harrington et al., 2006; Catchpole et al., 2007). Therefore marine fishery bycatch can be defined as the discarded catch of any living marine resource plus those retained as incidental catch (trash) and unobserved mortality due to a direct encounter with the fishing gear (Anon, 1999a).

The role of bycatch in degrading marine ecosystems has been made one of the most significant nature conservation issues in the world today (Hall et al., 2000; Lewison et al., 2004), with serious food-security implications up to 1 billion people who depend on fish as their principal source of protein (Anon, 2008). Although concern about resource damage due to bycatch in commercial and recreational fisheries can be found in the scientific literature from the mid-1970s, it became the most critical issue in the 1990s (Alverson et al., 1994; Kennelly, 1995; Alverson and Hughes, 1996; Hall et al., 2000).

2.1 Status of Bycatch in world fisheries

The first global estimate of bycatch was approximately 12 mt (Slavin, 1981). A detailed examination of bycatch in world fisheries was made by Saila (1983) who revealed that the minimum world discards of fish and shellfish were 6.72 mt in shrimp fisheries. This study forced the international fishery managers to focus on the issues of bycatch and discards, its documentation and search for solutions to reduce bycatch levels.
Andrew and Pepperell (1992) assessed the global bycatch in shrimp fisheries at 16.7 mt. Later, Alverson et al. (1994) estimated an annual bycatch in the global commercial fisheries at 28.7 mt of which an estimated 27.0 mt were discarded. Shrimp trawling contributed 11.2 mt (37.2%) of bycatch worldwide. According to this data, much of the discard in shrimp fisheries is mainly comprised of small tropical fishes. In temperate and sub-arctic waters, main portion of the discards were juveniles and adults of fishes of commercial value. In West Indian Ocean, India and Pakistan are contributing major share to the discards of shrimp fisheries (Alverson et al., 1994).

Most of the marine fisheries are mixed fisheries, directed at only a few commercial target species. However, a wide variety of bycatch species are captured along with the target species (Anon, 1996; Castriota et al., 2001). Some of these species also have economic value and are retained and commercialised, while others are discarded overboard for a variety of reasons (Saila, 1983; Alverson et al., 1994; Stobutzki et al., 2003). According to the estimations of FAO the global fish discard level was 20 mt (Anon, 1999b). Average annual global discards, had been re-estimated to be 7.3 mt during 1992-2001, based on a weighted discard rate of 8%, (Kelleher, 2004).

Bycatch includes individuals of target species smaller than the legal minimum landing size, juveniles of commercial species, individuals of threatened, endangered or protected species (Alverson et al., 1994; Kennelly, 1995; Lewison et al., 2004). However, a consistent understanding of bycatch is lacking due to several unresolved issues: definition, measurement and quantification.

Bycatch is by and large regarded as unavoidable, portion of the catch and it is not restricted to any particular gear type or any particular region of the world (Hall et al.,
2000). However, non-selective fishing gears such as trawls catch almost everything in their path and are generally considered to comprise greater bycatch rates than more selective gears such as longlines and purse seines (Anon, 1996). Trawling contributes approximately 35% in the global bycatch (Alverson et al., 1994). Shrimp fisheries produce about 16.4 mt of bycatch than other type of fisheries and among different fishing gears, bottom trawling accounts for a higher rate of bycatch production along with target species (Alverson et al., 1994; Bonfil, 2000; Koslow et al., 2001; Bergmann et al., 2002; Sanchez et al., 2004).

During 1998 the average annual global discards were estimated to be 20 mt and it came down to 7.3 mt in 2004 (Anon, 2004a; Kelleher, 2004). Though recent bycatch estimates have indicated considerable decline in the past decade (Anon, 1999a; Anon, 2004a; Anon, 2004b), bycatch still remains a major threat to biodiversity and long-term sustainability of fishery resources. The issue of bycatch in bottom trawl fisheries is of particular concern in tropical shrimp fisheries, where the weight of bycatch can be 5 to 10 times greater than the weight of the target species (Andrew and Pepperell, 1992). The diversity of species found in tropical waters is the main cause of the higher magnitude of discards found there and in tropical regions the trawl nets used to catch over 400 species in their nets (Anon, 2003a).

Worldwide the bycatch of commercial fisheries has become a great concern to fisheries managers and environmental and conservation groups due to its contribution to biological overfishing and to changing the structure of marine communities and/or ecosystems, with serious implications for marine populations and the overall health and sustainability of ecosystems (Anon, 1997; Rebecca et al., 2004). The first step towards understanding and solving the bycatch problem is to identify and quantify bycatches (Alverson et al., 1994; Kennelly, 1995; Borges et al., 2002). Onboard observations are the
most widely used approach for quantifying bycatches in commercial fisheries to record the required data during normal fishing operations (Saila, 1983; Alverson et al., 1994; Kennelly, 1995; Anon, 1996; Liggins et al., 1996).

Vaan beek (1998) studied the discarding in Dutch beam trawl fishery for the years 1976 to 1990. The study revealed that the annual amount of discarded fish in the Dutch beam trawl fleet was about equal to the annual landings. A total of 37 fish species were recorded in discards with more than 80% of the discards comprising of flatfish especially dab and plice species. The bycatch of non marketable discards in the fishery was estimated to be 25% of the total catch or 44% of the fish catch.

Stergiou et al. (1998) have made an attempt to assess discards for the commercial trawl fishery in Hellenic waters (Athens). The observations revealed that discard rate (i.e. discarded/total-catch) varied between areas and seasons that reflected the differences in local market demand and species composition. Therefore, the discard rate in autumn-winter 1993 was highest in the Saronikos Gulf and lowest in Cyclades. In contrast, in spring 1994 the discard rate recorded was similar for the Saronikos Gulf, Thracian Sea and Cyclades whereas it was lower in the Ionian Sea. With respect to fishes, the main non-commercial species discarded were Serranus hepatus, Lepidotrigla cavillone, Arnoglossus laterna, Macroramphosus scolopax, Scyliorhinus spp., Gobiidae, Callionymus spp. and Cepola macrophthalmia. The main commercial fish species discarded were: M. merluccius, M. poutassou, Trachurus spp., Pagellus erythrinus and Citharus linguatula which were generally discarded in small quantities. The quantities of M. merluccius that was discarded ranged in individual hauls from 0 to 12.0%, in the Saronikos Gulf, and from 0 to 8.6%, in the Thracian Sea; those of M. poutassou, between 0.0-9.6%, in the Saronikos Gulf, and between 0.0-3.0%, in the Thracian Sea; those of Trachurus spp., between
0.0-43.9%, in the Saronikos Gulf, and between 0.0-20.4%, in the Thracian Sea; and finally those of 7: *M. capelanus*, between 0.0-5.6%, in the Saronikos Gulf, and between 0.0-17.5%, in the Thracian Sea.

Survey data from Halong (408 vessels in 1996 - 1997) indicated that catch composition (%) of trash fish landings in the Gulf of Tonkin fluctuated between 27.2% and 51.0% and in the Southeast area from 15.9% to 68.1% except depth strata > 200m. The main species of trash fish consisted of fish species from following families: Leiognathidae, Apogonidae, Engraulidae, Triglidae, Callionymidae, Siganidae, Monacanthidae, Lophiidae, Antennaridae and many juvenile species of other families, such as Serranidae, Synodontidae, Sparidae, Scombridae, Mullidae, Nemipteridae, Priacanthidae, Carangidae and Clupeidae (Son et al., 2005).

Costa et al. (2008) studied the issue of bycatches of crustacean and fish trawlers of the southern Portuguese coast. The results showed that total bycatch exceeded target catch in both types of bottom trawl, even though it was much higher in fish (80.4% in kg) than in crustacean (59.5% in kg) trawls, while quantities of both commercial bycatch and discards were quite similar in the two types of bottom trawls. In all seasons, fish trawl total bycatch was greater than the target catch, especially in winter when it comprised almost 90% of the total catch. Of the total number of species (n = 255) identified during their study, 137 (53.7%) were fish, 36 (14.1%) were crustaceans, 56 (22%) were molluscs and 26 (10.2%) were other invertebrate species from nine different taxonomic groups.

Bycatch and discards of trawl fisheries at the Mediterranean coast of Egypt was examined by Alsayes et al. (2009) revealed that the non target catch comprised 52% and 37% of the total catch of trawl net during spring and summer seasons, respectively.
By-catch comprised 24 finfishes in that, 13 had commercial value. On the other hand 5 species of crustaceans appeared. The bycatch was dominated by *Pagellus erythrinus* comprising 87.81% by number and 56.61% by weight of that catch. *Lithognathus mormyrus, Boops boops, Pagellus acarne, Arisoma balearicum* and *C. flamentosus* were also found in the bycatch with higher percentage in comparison with the other fish species. Invertebrates (Cephalopods and Crustaceans) comprised 23.15% by weight of the by-catch. However, the appearance of 13 commercial fish species among a whole number of 24 species comprised the bycatch indicated that the fish populations of commercially important species were supposed to be drastically affected as a result of trawling in their living grounds.

2.1.1 Bycatch landings of Asia Pacific countries:

**Bangladesh**

The Bangladesh trawl fishery regulations limit the finfish caught, prescribe minimum mesh size, prohibit commercial trawlers in waters less than 40 m deep and prohibit discards. Rahman (2001) noted that these regulations were not being observed by the trawl and even operated in shallow waters of 10 m depth. Kelleher (2005) accounted a 4:1 ratio of shrimp trawl catch to discards. But according to Rahman (2001), shrimp landings represented just 4.8 percent of the total catch composition in waters deeper than 30 m, which had been accounted entirely by commercial trawlers. The results were supported by Ahmad (2005) based on a survey of 44 commercial trawlers. However, shrimp landings represented only 1.5 percent of the total catch in waters less than 30 m, which was partly commercial catch and partly artisanal catch. Bycatch was thus more than 20.8 times greater than the catch of shrimp in deeper waters and 67 times greater than the shrimp catch in shallower waters. Kelleher (2005) estimated 71,000 t (17%) of low value
bycatch (trash) for the year 2001-2002. According to Davies et al. (2009) the total estimated bycatch in the trawl fishery was 10.82 lakh t.

**China**

Chinese fisheries experts estimated trash fish and low value fish, including juveniles of commercial species, to be 70 percent of China’s marine catch during 1990 and this indicated that the percentage of low value and trash fish had increased over the past two decades (Wang and Zhan, 1991). By 1999, the catch of low-value pelagic fish consisted primarily of juveniles, and the biomass was reported to be in very serious decline (Jin, 2000). As per the studies of FAO, during 2001 China produced 53.16 lakh t (38%) of low value bycatch (Kelleher, 2005). Official Chinese statistics for 2003 showed 21.6 lakh t of low value and trash fish catch, out of a total marine catch of 97.3 lakh t. However, as much as 50 lakh t of trash fish was used for fishmeal, livestock and aquaculture feed (Grainger et al., 2005). The estimated bycatch of 50 lakh t used for non-human consumption as of 1999 would represent 68.5 percent of total Chinese marine catch (Davies et al., 2009).

**India**

There is substantial evidence that the bulk of the catch consisted of trash and low value fish, primarily juveniles were being landed during 1990s, driven by rapidly growing demand in the beginning of late 1980s from the fish meal industry, which increased prices for such catch (Wood et al., 1992). A study conducted by Luther and Sastry (1993) on India’s marine fisheries noted that the bulk of marine landings in all of its maritime states consisted of juvenile fish. In 1999, Menon et al. (2000) investigated the impact of coastal bottom trawling on demersal fishes and macro benthos along the west coast estimated that bycatch ranged between 56 percent and 82 percent, respectively.
Bhathal (2005) estimated total shrimp catch as of 2000 at 4.5 lakh t, which would imply that the shrimp trawl fleet generated an additional 18 lakh t of bycatch. Chandrapal (2005) estimated that total landed non-shrimp catch was 13 lakh t annually, combined with the shrimp catch the total landed trawl catch was of 17.5 lakh t. Study conducted by Kelleher, (2005) revealed that India produced 2.7 lakh t of bycatch in 2003, trawling was the most dominant gear responsible for trashfish landings. The earliest survey of bycatch in Indian marine fisheries, carried out by CMFRI in 1979, found that 79 percent of total landings in the shrimp trawl fishery consisted of non-shrimp catch (Anon, 2006a). This huge catch of juveniles was due to the use of extremely small cod-end mesh size (as low as 8–10mm, only one-fourth of the 35mm size that is legally required (Kumar and Deepthi, 2006). The estimated total trawl bycatch was 22.5 lakh t, the bycatch representing 56.3 percent of the estimated total marine catch (Davies et al., 2009).

Vietnam

The annual total of ‘trashfish’ caught by the Vietnamese fleet was estimated at 9.3 lakh t by the Vietnam’s Research Institute of Marine Fisheries, all of which is used for aquaculture feed or feed ingredients. However, the entire Vietnamese trawl fleet geared to catch very small shrimp and immature fish in ways that failed to conform to the regulation of minimum net mesh size (Hoi et al., 2006). Bycatch in the shrimp fleet accounted for 1lakh t of shrimp, varying from 60 to 80 percent (Edwards et al., 2004). According to Marcano (2006), trashfish catch now between 50 and 60 percent of the trawl catch in many areas but up to 80 percent in at least one province.

2.2 Reasons for bycatch discards

Fish are discarded for a number of reasons. Sailia (1983), Northridge (1991), Murray et al. (1992), Pikitch (1992), Murawski (1993), Clucas (1997), Jennings and Kaiser
Morizur et al. (2004), Anon (2005b), Chandrapal (2005), Zacharia et al. (2006), Manojkumar and Pavithran (2012) have given the following reasons for discards:

- Fish of wrong species - Fishes which are not of the target species for the particular operator.

- Fish are of the wrong size - Fish size which command too low a price in the market or which are below the minimum legal landing size.

- Fish are of the wrong sex - Usually where gender is important from the processing and marketing point of view.

- Damaged fish - Caused by gear or predation in nets or mishandling.

- Fish are incompatible with the rest of catch - Species with slime or causing abrasion that could cause damage to the target species.

- Fish that are poisonous or otherwise considered inedible.

- Fish which spoil rapidly causing problems for the rest of the catch.

- Lack of space onboard - Where fishing operations are successful and target species take precedence over lower value or non-target species.

- High grading - Certain attributes of a fish make it more marketable and therefore more valuable than others which are discarded.

- Quota limits - This may involve discarding of fish species that has exceeded the quota limits.
➢ Prohibited species - This involves the discards of particular species that are protected legally.

➢ Prohibited season - Where time bound constraints are made on catching particular species.

➢ Prohibited gear - Fishes caught using prohibited gear.

➢ Prohibited fishing grounds - Fishing ground may be closed for capture of particular species but open for others - if the wrong species is caught.

2.3 Bycatch Indian Scenario

2.3.1 Quantification of bycatch and discards:

In tropical countries like India, bycatch issue is more complex due to the multi-species nature of the fisheries. During shrimp trawling large quantities of finfish bycatch landed that include significant amount of juveniles. The preliminary assessment of bycatch and discards in India showed that 79.18% (3,15,902 t) of total shrimp trawl landings as bycatch in India, maximum being in Gujarat (92.58%), followed by Tamil Nadu (91.04%) and Pondicherry (86.52%). The estimate further showed that the bycatch utilized either for human consumption or as fish meal and fish manure (George et al., 1981).

Sukumaran et al. (1982) made an appraisal of trawl fishery of Karnataka to assess trawl bycatch off Mangalore and Malpe in Karnataka during 1980-82. They reported that shrimps contributed only 13% of average annual trawl catches and bycatch comprised as high as 85% of the trawl landings.
Kurup et al. (1987) in their study on an appraisal of the marine fisheries of Karnataka & Goa, reported that, the annual bycatch in trawl fishery of Karnataka was estimated as 85% of the total trawl catch, stomatopods being the major constituent. It was observed by Rao (1988) that the quantity of bycatch discarded in Visakhapatnam (India) depended on the demand for finfishes in the external and domestic markets.

Gordon (1991) estimated the bycatch levels in India as part of Bay of Bengal Programme of FAO. According to his observations bycatch landed by shrimp trawlers in east coast of India was about 90% of total catch and the quantity of bycatch being discarded by the trawlers was estimated to be 1,00,000-1,30,000 t.

Menon (1996) studied impact of bottom trawling on exploited resources along the southern region of Karnataka, Kerala and Tamil Nadu and estimated that target groups such as shrimp (16%) and cephalopods (4%) together constituted only 20% and others such as finfishes (65%) and benthic organisms 15% constituted the rest of the trawl landings. The quantity of bycatch landed by trawlers in the above states was estimated at 43,000 t, of which 81% has accounted by stomatopods. Another 87,000 t of unmarketable benthic organisms was estimated to be discarded in order to save fishhold space for high-priced items, most of the by-catch was thrown overboard.

Pillai (1998) reported that the bycatch landings along Cochin, Visakhapatnam and in Saurashtra region (Gujarat) varied from 70 to 90% and average discards was 15 to 20% from shrimp trawling. Bycatch landing was maximum in Gujarat (90 to 95%), followed by Tamil Nadu (80 to 90%), Andhra Pradesh (80 to 85%), Karnataka (80 to 85%), Orissa (75 to 80%), Maharashtra (70 to 75%) and Kerala (65 to 70%).
CMFRI carried out an investigation on the impact of coastal bottom trawling on demersal fishes and macrobenthos in Karwar, Mangalore, Kochi, Mandapam and Kakinada. The study revealed that the ratio of target : bycatch along the southwest and southeast regions of India were 1 : 4.6 and 1 : 1.26 respectively (Menon et al., 2000).

The characterization and quantification of bycatch and discards along Kerala coast was studied by Kurup et al. (2003). The discarded quantity by bottom trawlers estimated during 2000-2001 and 2001-2002 was 2,62,000 and 2,25,000 t respectively. The dominant varieties among the discards were finfishes, crabs and stomatopods. The group wise average discards during the study period showed that finfishes (95,000 t) were the major components, followed by crabs (68,000 t), stomatopods (40,000 t), gastropods (22,000 t), juvenile shrimps (5,000 t), soles (3,000 t), jelly fishes (3,000 t), cephalopods (2,900 t), echinoderms (1,800 t), sea snakes (1000 t), and eggs (890 t).

The use of the term “Trash Fish” varies from country to country and can change both seasonally and with locations. One category of trash fish is those not used for direct human consumption, which may be either landed or discarded at the sea itself. The other category is low value fish used for human consumption. In a country like India where marine fishery consist of multispecies composition, the occurrence of by-catch consisting of several species of fish is bound to happen, especially for the trawler operators with regard to on-board handling, preservation, storage, processing and marketing. Since the return from by-catch sometimes known as trash fish is poor compared to the valuable catch of shrimp and table fish (Chandrapal, 2005).

Jayaraman (2004) estimated trash fish to constitute 10-20% of total catches (2,71,000 t) landed by trawlers operating along Indian coast. The demand for targeted
resources has paved way for indiscriminate bottom trawling along the coast with an ultimate result of massive wastage of low value, high volume bycatch including a wide spectrum of non-edible benthic biota. Kelleher (2004) has estimated total bycatch discards in Indian fisheries at 57917 t, which formed 20.3% of the total landings. The small cod end mesh of bottom trawlers has also exploited juveniles and sub-adults of commercial species in large quantities.

Zacharia et al. (2006) assessed the bycatch and discards associated with bottom trawling along Karnataka coast (India). They reported that bycatch quantity from trawlers was 56,083 t in 2001 and 52,380 t in 2002, which formed 54% and 48% of total trawl catch, respectively. The quantity discarded was 34,958 t (33.9%) in 2001 and 38,318 t (35.1% of total catch) in 2002. Discards were more in post-monsoon months than in other months. Annually 33,098 t of bycatch landed in Multiday trawlers (MDT) and in Single day trawlers (SDT) the quantity was 21,109 t. About 30% of total catch from MDT was discarded (21,336 t) whereas it was about 44% from SDT (15,301 t). In 2002 maximum bycatch was recorded in March followed by May in multiday trawlers. The most dominant group among bycatch was stomatopods in SDT. It formed over 39% followed by finfishes (36%) while finfishes were the dominant group in MDT (69%). The pooled data for two years showed that, the discard rate ranged from 7.5 kg h\(^{-1}\) to 27.0 kg h\(^{-1}\) in SDT and from 2.0 kg h\(^{-1}\) to 16.7 kg h\(^{-1}\) in MDT. During single day fishing, stomatopods formed the most dominant component among discards (over 52%) but in multi-day fishing various finfishes dominated the discards.

Dineshbabu et al. (2010) estimated that a total 1,601 t of fishes were landed by single day trawlers operated from Mangalore. Out of which 583 t (36.44%) were of non
edible low valued fauna (trash). The highest trash fish landed was during December (47.2%). The bycatch was dominated by stomatopods followed by finfishes, whereas, non edible crabs, molluscs, cephalopods and other invertebrates were present in lesser quantities. The multiday trawlers landed 65,589 t, of fishes out of which 2,418 t (3.69%) were landed as trash. The low value bycatch caught earlier to the last two days were discarded due to lack of space and the data from the sampled trawler showed that 14% of the catch was discarded during the process which amounts to be 9,199 t.

In Karnataka on an average 1,20,000 single day trawler units operated annually with an effort ranging from 96,012 (2005) to 1,37,240 (2003) and the quantity of fish landed decreased from 26,708 t (1997) to 24,882 t (2004), with an average of 32,405 t. In case of MDT, the annual units operated remained more or less same throughout the period of observation. The fishing units operated ranged from 22,836 (1998) to 31,795 (2008) with an average of 27,678 units. But there was phenomenal increase in hours operated and the landings by MDT. It was noticed that, the fishing duration was below 13 lakh hours in 1998 which has increased to more than 33 lakh hours in 2008. The catch increased from 47,897 t (1996) to 1,53,117 t (2008). Even though there was a substantial increase in fish landing, similar increase was not reflected in the value realised from the fishery (Dineshbabu et al., 2012).

An estimated 25,067 t of LVB valued at Rs. 25 crores was landed by multiday trawlers (MDT) at Mangalore Fisheries Harbour. The landing increased from 15.3% of total landing (14,837 t) in 2009 to 25.4% in 2010 (25,678 t). The high demand for trash fish had been the major reason for increased LVB landing. In single day trawlers, 40% of the catch was landed as trash, which was dominated by stomatopods. Landing of low value
bycatch showed an increasing trend of 16.7% at Calicut (11,694 t) and nearly 27.4% at Visakhapatnam (19,385 t). Low value bycatch formed 15% (4,765 t) of the total trawl landing in Chennai, of which fishes formed 71%. In Versova, Mumbai an estimated 2,294 t of LVB (39% of total catch) was landed. Bycatch fetched Rs. 5.8 crores at Calicut and it was also noted that at Mangalore, highest percentage of juvenile fishes by weight in bycatch was of *Nemipterus* spp. (4,023 t) which resulted in an annual revenue loss of Rs.16.5 crores. The economic loss due to discards of juvenile fishes by trawlers at Calicut was estimated as Rs.6.6 crores (Anon., 2011b).

Dineshbabu et al. (2012) reported that, the fish landing of SDT at Mangalore in 2008 was 1,946 t, of which 74% was of edible grade and 26% was LVB. Where as in 2009, out of 1,568 t landed, the composition was 53% and 47% respectively. Stomatopods were the major dominant components of trash forming 63 per cent in 2008 and 43 per cent in 2009. In 2008, a total of 1,00,002 t of fishes were landed by MDT out of which 97,381 t (98%) were considered as edible purpose and rest was trash. The fish landing reduced to 83,148 t out of which only 70,429 t (83%) were landed as edible and the rest were landed as LVB (trash). More than 300 species of fishes and shell fishes were identified from trawl landings of Mangalore and most life stages of many of the species were represented in LVB. Lizard fishes, puffer fishes, threadfin breams and flatheads were the major contributors to trash. It was also noted that in recent years, the percentage of oil sardine in the trash showed an increasing trend.

According to Manojkumar and Pavithran (2012) the estimated trawl catch at Calicut for the period 2007-2011 ranged from 26,452 t to 47,184 t. The trawl catch showed a declining trend from 2007 to 2009. However, the catch showed an increasing trend in
2010 with an estimated total catch of 34,452 t by an effort of 0.76 million fishing hours and the increasing trend continued up to 2011.

The studies conducted on the year wise bycatch showed that, bycatch formed 34,138 t in 2007, which declined to 20,956 t in 2009. Landings of bycatch showed an increasing trend from 28,468 t in 2010 and reached 41,052 t in 2011. Bycatch landing was highest in March (4291 t) and lowest in December (1778 t). The bycatch rate ranged between 23.18 kg h\(^{-1}\) in January and 74.87 in August. Year wise fluctuation in the bycatch rate had shown an increase from 27.83 (2007) to 50.18 kg h\(^{-1}\) (2011), the average catch rate for this period being 34.66 kg h\(^{-1}\).

The contribution of low value bycatch (trash) varied from 9,116 t (2009) to 14,118 t (2007) and average for the period was 12,241 t. The catch rate of low value bycatch ranged from 11.57 (2007) to 15.62 kg h\(^{-1}\) (2008). The monthly contribution of low value bycatch ranged between 730 t (August) and 1,716 t (May) and the catch rate ranged from 10.86 (September) to 19.59 kg (October). Whereas the trawl discards varied between 1,957 t (2011) and 6,264 t (2008) and the average discard landing estimated for this period was 3,367 t. Analysis of data showed that the quantity of trawl discards had come down and it showed less than 9 % of the trawl catch in this region.

A study on an appraisal of trawl fisheries of India with special reference to the changing trends in bycatch utilization carried out by Dineshbabu et al. (2014) revealed that at Veraval, it is a regular trend to land most of the fishes caught by trawlers and the LVB landing during 2007-2011 showed a steady increase from 24% to 33%. The percentage of LVB landed remained around 5% in major landing centres of Mumbai, and the trash fish landed were only those caught during the last day of the voyage. In Mangalore, as in other
centres, single-day trawlers landed all the catch to shore and the LVB consisted of 30 to 40% of total catch. On the other hand, multiday trawlers brought the trash (LVB) in semi-preserved form suitable for fish meal and fertilizer producers. In Mangalore also a strong market chain exist for the LVB and the business is becoming a very prominent economic activity in fisheries of Karnataka. In Mangalore fisheries harbour landings of LVB showed phenomenal increase, which formed only 3% (3,000 t) of the trawl landing in 2008 increased to 26% of the total fish landed (12,000t) in 2011, the percentage of LVB to the total trawl landings was 3, 14, 21, 26 in 2008, 2009, 2010 and 2011 respectively. This increase in LVB landing was the result of increased demand from an array of fish meal plants operating all along the Karnataka coast. In Calicut also there was high demand for the LVB by fishmeal plants and in this centre, LVB landing in 2011 was 12,000 t forming 26% of the landed catch. In Chennai, the estimated LVB landing was 13% (3,000 t) of the total landing in 2008 which increased to 17% in 2011 (5,800 t). In Visakhapatnam, estimated LVB landed showed a steady increase from 2% (705 t) of the landing in 2008 to 21% (19,000 t) in 2011.

They also noticed that the price fetched by the LVB mainly varied with its composition. LVB dominated by finfish was in much demand and in Mangalore the trash landed in semi preserved form by multiday trawlers fetched a rate as high as Rs. 12/kg and that was mainly used for fish meal preparation. Whereas single day trawlers landed trash dominated by mollusc and crustacean fetched only Rs. 4/kg, which was mainly utilised for drying for low cost fishmeal. In Mangalore and Calicut, finfish constituted highest to the LVB landings (85 to 90%) than Veraval, Mumbai, Chennai and Visakhapatnam where finfish composition in LVB remained below 65 percent throughout the study period.
With the decline of the shrimp catch the bycatches began to contribute significantly to the overall income of the shrimp trawlers (Clucas, 1998). Along the west-coast of India, most of the bycatch is landed and utilized for fishmeal and manure production (Zynudheen et al., 2004; Kumar and Deepthi, 2006; Dineshbabu, 2011). Bumper landing of oilsardine in 2007 led to rapid growth of fish oil and fish meal plants all along the coastline and the capacity of the existed plants were increased for boosting the production of fish oil and meal. However, since 2008, oilsardine catch showed a reducing trend from 94,000 t in 2007 to 81,000 t in 2008. The oilsardine production further reduced by 20% compared to the previous year. This reduction in oilsardine landings resulted in a crisis of raw material to meet the demand for fishmeal. Trash fish provided a viable alternative for fish meal production. Multiday trawlers who were already in an economic crisis decided to utilise this opportunity and started to land an average rate 2 t/trip. The trash fish in the trawler is stored with minimum ice and usually landed in a semi-rotten form and started to sell Rs. 8-10/kg (Zynudheen et al., 2004; Dineshbabu, 2011). It is significant to note that the trash contained juveniles of all commercial species and those in the early stages of development, which were invariably discarded leading to the depletion of the resources (Pillai, 1998; Pillai et al., 2004; Dineshbabu, 2011).

2.3.2 Bycatch Species characterisation:

The trawl fishery of Mangalore has undergone a significant change since its introduction, and study of bycatch has been the focus of research during the last two decades. For assessing the sustainability of marine fisheries production it is imperative to understand the species composition and juvenile composition of the fishes in LVB. Sujatha (1995) studied finfish constituents of trawl bycatch off Vishakapatnam and found that trawl catches included over 11% of the economically important bycatches of finfishes. The
discards included 228 species belonging to 68 families had been identified as a constituent of finfish bycatch landed by small trawlers based at Visakhapatnam. The bycatch constituted not only small-sized and non-edible species, but also juveniles of commercially important species.

The trash fish sent to fish meal plants in Tamil Nadu, when large quantities were caught, mostly comprising balistids. *Decapterus* and lizardfishes, posed the problem of disposal locally. Others commonly included in LVB were small-sized sciaenids, threadfin breams, crabs, and species of *Fistularia, Holocentrus, Priacanthus, Scolopsis* and *Upeneus* (Joel and Ebenezer, 1996). Along the southern region of Karnataka, Kerala and Tamil Nadu during the years 1985-90 period the discarded by-catch included many low-valued ground fishes (20 genera), crustaceans (26 genera), gastropods (23 genera), bivalves (15 genera), polychaetes, anemones; sponges, echoderms (10 genera), gorgonids, ascidians, echiurids, jelly fishes *etc*, besides the unmarketable juveniles of fishes, prawns, crabs and cephalopods. The maximum discards were represented by stomatopods in SDT and finfishes in MDT. The post harvest loss of by-catch including juveniles of commercially important species and many taxa of benthic organisms might also seriously affect the coast-ward feeding migrations and predator-prey relationships of component species in the affected habitats (Menon, 1996).

As per the observations of Pravin and Manohardoss (1996) 87 species belonging to 42 families constituted 82.7 per cent of the low value by-catch landed by mechanised trawlers operating off Veraval. Sciaenids were the major group contributing 15.6 per cent, followed by engraulids (12.84%), ribbon fishes (8.9%), penaeid and non penaeid prawns (8.2%), squids and cuttle fishes (7.7%), polymemids (4.9%), white fish (4.2%), nemipterids (3.9%), leiognathids (3.3%), carangids (2.8%), flat fish (2.7%) and others...
(7.7%). Balance 17.3 per cent was constituted by shells, jelly fish, squilla, crabs, sea snakes and unidentified groups.

Studies on the impact of bottom trawling on the ecology of fishing grounds and living resources of the Palk Bay and the Gulf of Mannar had shown the presence of 185 species in the bycatch, represented mainly by ground fish, stomatopods, shrimps, gastropods, bivalves, crabs, echinoderms, sea weeds and sea grass (Anon, 2002). Kurup *et al.* (2003) recorded that the discards from bottom trawlers of Kerala coast were represented mainly by epifaunal species and juveniles of commercially valuable species and the discards were represented by 103 species of finfishes, 65 gastropods, 12 bivalves, 8 shrimps, 2 stomatopods, 12 crabs, 5 cephalopods, 3 echinoderms and 4 jellyfishes. It was also observed that though discarding of bycatch was practiced in the case of multi day trawling, its magnitude and species composition were not properly assessed. They opined that a comprehensive study that includes landed bycatch and at-sea discards only reveal the complete picture of the impact on the biodiversity caused by the bottom trawling. Squilla, though doesn’t have economical value, has significant ecological importance as it forms one of the food item of a large number of demersal organisms (Mohamed, 2004).

Bhathal (2005) assumed that no discards exist for trawl fisheries in India presumably due to burgeoning trash fish demand in poultry and aquaculture feed sectors in the last two decades. From the Mangalore - Malpe trawl landing base the young/juvenile fish bycatch was 1549 t in SDT and 9077 t in MDT forming 5 to 15% of total catch (SDT) and 5 to 28% (MDT) most of which were unmarketable and hence sold along with non
edible biota. The major constituents were nemipterids, *Epinephelus* and lizardfishes in MDT; while flat fishes, silver bellies and sciaenids dominate in SDT (Anon., 2006b).

Bycatch composition of trawl fishery of Malpe and Mangalore was examined by Zacharia *et al.* (2006). The discarded catch in MDT consisted of 53 species of fishes (23 always discarded), 12 crustaceans (6 always discarded), 27 molluscs (22 always discarded) and 7 other invertebrates (always discarded). In the SDT, 53 species were seen in the landings and 60 in discard which comprised 35 species of fishes (10 always discarded), 6 crustaceans (3 always discarded), 14 molluscs (14 always discarded) and 5 other invertebrates (2 always discarded). The catch rate of discards was high during monsoon in MDT and pre-monsoon in SDT. Juveniles of various groups constituted an important bycatch of trawl fishery of Karnataka formed about 15.9% of the total catch in SDT and 23.5% in MDT at catch rate of 7.8 kg h^{-1} and 9.4 kg h^{-1} respectively.

Bijukumar, (2008) conducted study on biodiversity of trawl bycatch at Neendakara, Sakthikulangara, Munambam, Ponnani, Puthiyappa and Azheekkal of Kerala coast and recorded 534 species associated with the trawl bycatch of Kerala coast, which included 10 species each of Porifera and Cnidaria, 3 species of Annelida, one species each of Bryozoa and Sipunculida, 135 species of Mollusca, 72 species of Arthropoda, 18 species of Echinodermata, 279 species of Pisces and 5 species of Reptilia.

Bycatch composition of trawl landings of Kerala coast was assessed by Bijukumar and Deepthi (2009). Overall 217 species of fishes recorded in the trawl bycatch, classified under 21 orders, 88 families and 155 genera were represented predominantly by demersal (79 species) and reef-associated forms (78 species). The study further revealed that the dominant fraction of fish fauna (73%) of the trawl bycatch was represented by 159 species
which belonged to mid level carnivores included in the trophic level 3.0-3.99. The fish faunal diversity in the trawl bycatch significantly varied at different trophic levels. Presence of large number of mid level carnivores in the trawl bycatch may indicate large scale removal of top level predators from the ecosystem.

As per the observations of Dineshbabu et al. (2010) a total 35 species of finfishes, 20 species of crustaceans, 20 species of gastropods, 3 species of cephalopods, 2 species of stomatopods, 3 species of echinoderms, 2 species of coelenterates and one sea snake consisted the bycatch from single day trawlers. In multiday trawlers, the bycatch was constituted by edible species and biota like non-edible species of crabs, gastropods, echinoderms, gorgonids and sea snakes. Out of the 202 species identified, 45 species were of commercial value to the fishery of Mangalore constituted by 38 finfish species, two species of cephalopods, three species of shrimps, one species of lobster and edible crab each. *Saurida tumbil* contributed a major portion to the bycatch by weight (12.5% among commercial species and 4.7% in the total discards) and *Photopectoralis bindus* contributed maximum (33% among commercial group and 21.1% among overall discards) by numbers. Month-wise frequency of occurrence of species in the bycatch showed that as many as 14 commercial species invariably in all the months. *Platyccephalus* sp. and *Saurida tumbil* were observed in most of the sampling days from September to June.

Dineshbabu et al. (2012) recorded a total of 123 species from trash landing of SDT at Mangalore. Stomatopods were the major components of the trash forming 63% in 2008 and 43% in 2009. Seasonal trends in landing of trash by single day operating trawlers showed that highest percentage in March (46%) in 2008 and in February (63%) in 2009. During 2008-2009 a total 198 species were identified from discard samples of MDT.
Among them, 116 species of finfishes, 31 species of gastropods, 4 species of bivalves, 7 species of cephalopods, 13 species of shrimps, 3 species of stomatopods, 21 species of crabs, 3 species of lobsters and juveniles of unidentified sharks and rays were recorded. *Saurida* spp. contributed maximum portion to the low value bycatch by weight (12.65%) in 2008 followed by *Lagocephalus inermis* (11.2%) and during 2009 the species *Lagocephalus inermis* formed highest constituent (13.6%) followed by *Nemipterus* spp. (11.4%).

Gibinkumar et al. (2012) identified 281 species in the trawl catch, off southwest coast of India. The bycatch included 191 species of fishes, 11 species of shrimps, 3 species of lobsters, 13 species of crabs, 11 species of cephalopods, 44 species of molluscan shells, 2 species of echinoderms, 2 species of jelly fishes, 2 species of stomatopods and one species each of sea snake and sea turtle. A total one hundred and ninety-one species of fishes belonged to 12 orders and 59 families and 109 genera. Eleven shrimp species belonging to 4 families and 13 crab species belonging to 5 families had been identified. Eleven cephalopod species belonged to 3 orders and 3 families. Molluscan species belonged to 22 families while jellyfishes belonged to 2 families.

Manojkumar and Pavithran (2012) reported that, among low value bycatch landed by trawl catch at Calicut, scads (20.57%) contributed highest, followed by lizardfishes (14.88%), soles (14.23%), *Thryssa* (4.29%), sciaenids (4.75%), other carangids (3.55%), silverbellies (3.48%) and stomatopods (0.67%) were other dominant low value resources found in the bycatch. The discarded portion of the catch comprised 178 species of fishes and shellfishes. Finfishes comprised mainly low value and juvenile fishes were the main component of the discards and it formed 63.15%. Bulk contribution of fishes was noticed
in February (86.18%) against the lowest in November (29.2%). Among fin fishes 124 species were found in the discards. The crustaceans, molluscs and miscellaneous items contributed 22%, 7.28% and 7.22% respectively.

Dineshbabu et al. (2014) observed that the demand and price of LVB is determined by the species composition of LVB and finfish dominated LVB had better demand from fish meal plants. A total 95 species of finfishes, 27 species of crustaceans and 20 species of molluscs were identified from LVB landings at Mangalore during 2007-2011. *Lagocephalus inermis* (12.80%) contributed a major portion to the bycatch by weight, followed by *Saurida* spp. (11.705), *Decapterus* sp. (10.63%) *Sardinella longiceps* (8.59%) *Nemipterus* spp. (8.56%), Lesser sardines (5.93%), *Platycephalus* sp. (4.06%) *Aлепes* sp. (3.88%), *Rastrelliger kanagurta* (3.64%), *Dussumieria acuta* (3.49%), *Trichiurus lepturus* (3.41%), *Thryssa* sp. (3.25%) Eel (2.46%), *Leiognathus* spp. (2.21%), *Charybdis* spp. (1.79%), *Cynoglossus macrosoma* (1.64%), *Oratosquilla nepa* (1.56%), shrimps (1.32%), *Fistularia petimba*, (1.31%) and other species. Further, it was also noticed that the species composition of LVB in the south west coast of India showed higher percentage of finfishes than those in east coast and that of northwest coast of India.

### 2.3.3 Juveniles and their impact on loss of fishery resources

Bycatch and discards had created perceptible impacts on biological and ecological aspects of many species. A number of authors have discussed the disadvantages of bycatch and its effects (Prado, 1997; Hall et al., 2000; Linnane et al., 2000; Horsten and Kirkegaard, 2003; Anon, 2005b; Kumar and Deepthi, 2006; Zacharia et al., 2006; Manojkumar and Pavithran, 2012).
Generally bottom trawl fishing has been found to be more destructive in structurally complex and biodiversity-rich marine habitats that leads to community changes in benthos, reduction in biodiversity, biomass and size of organism (Goni, 1998; Watling and Norse, 1998; Jennings and Reynolds, 2000; Thrush and Dayton, 2002; Revil and Jennings, 2005). Most of the discards comprised of juveniles of fishes and shellfishes and therefore discards may be a significant part of the fishing mortality.

Observations of Sivasubramanyam (1990) revealed that 50% of the bycatch sample studied was immature fish in trawlers from Bay of Bengal. Luther and Sastry (1993) studied the occurrence of spawners, juveniles, and young fish in relation to fishery seasons of some major fishery resources of India. They observed a bulk of the landings in different maritime states in different fishery comprised of juveniles.

Menon (1996) estimated that 6,200 t of juvenile fish and prawns were discarded back into the sea during 1980-84 along the south-west coast of India. Pillai (1998) also observed that 40% of the catch from Indian seas was constituted by juveniles.

Kurup et al. (2003) recorded that the discards from bottom trawlers of Kerala coast were represented mainly by epifaunal species and juveniles of commercially valuable species. The small cod end mesh of bottom trawlers has also exploited juveniles and sub-adults of commercial species in large quantities. From the Mangalore - Malpe trawl landing base the young / juvenile fish bycatch was 1,549 t in SDT and 9,077 t in MDT forming 5 to 15% of total catch (SDT) and 5 to 28% (MDT) most of which are unmarketable and hence sold along with non-edible biota. (Jayaraman, 2004).

It was observed by Zacharia et al. (2006) that, in Karnataka, juveniles contributed 36% of discards (15.9% of total catch) in single day fishing and 78% (23.5% of total catch)
in multi-day fishing. Annually 14,400 t of juveniles of finfishes, 2,448 t of shrimps, 1,673 t of cephalopods and 1,702 t of crabs besides 4,059 t of juveniles of other groups were removed by bottom trawling.

Discarding and juvenile exploitation are two important factors which have been impacting negatively on the stocks as well as on the fishery economy. The mortality due to fishing could be much higher than that estimated from the resource landed, as discards are not taken into consideration. The results of the studies on geotemporal distribution of juvenile and adult threadfin breams, *Nemipterus mesoprion* in trawling grounds off Karnataka for the fishing year 2007-2008 showed that only 30% of *N. mesoprion* (in terms of numbers) caught were landed as commercial catch and the rest (70%) was discarded as they were juveniles of low commercial value (Dineshbabu *et al.*, 2009).

Dineshbabu and Radhakrishnan, (2009) projected that the threadfin breams exploited by trawlers of Mangalore showed that the fishery loss due to juvenile catch of the species in Mangalore was 7% by weight and 22% by value, and the economic loss was estimated at Rs. 286 lakhs annually. An estimated 63.7% (by numbers) of bycatch was constituted by juveniles of commercially important fishes causing significant damage to the stocks of these species. In terms of weight, commercial species constituted 37.4% of total bycatch (Dineshbabu *et al.*, 2010).

It was also noted that at Mangalore, highest percentage of juvenile fishes by weight in bycatch was of *Nemipterus* spp. (4,023 t) which resulted in an annual revenue loss of Rs.16.5 crores. The economic loss due to discards of juvenile fishes by trawlers at Calicut was estimated at Rs. 6.6 crores (Anon., 2011b).
Dineshbabu *et al.* (2012) in their study on spatio-temporal analysis and impact assessment of trawl bycatch of Karnataka to suggest operation based fishery management options observed that juveniles of commercial species formed 34% of the discards and in terms of number they formed 44% during 2008-2009. The discards consisted almost all commercial species and juveniles of pelagic fishes. In 2008-2009 total 37,533 t of discards were estimated for Mangalore Fisheries. Juveniles of *Platyccephalus* sp. comprised about 2,733 t in discards during this period and the discarded number estimated was 464 million. *Nemipterus randalli*, one of the highest contributor to trawl landings at Mangalore also contributed considerably to the discards and the quantity discarded in weight and numbers were 1,341 t and 333 million respectively. Juveniles of high value resources like, seerfishes, cobia, cephalopods, shrimps, groupers and snappers were also found in considerable quantity and numbers in discards.

### 2.4. Role of Bycatch Reduction Devices

Bycatch Reduction Device (BRD) is defined as any modification designed that can be incorporated in a fishing gear in order to exclude or reduce non targeted and unwanted catch in a fishing system and thereby making it more selective. BRDs are also known as trawl efficiency devices or trash excluder devices (Robins-Toeger, 1994). Turtle Excluder Devices (TEDs) are a specific type of BRD design to exclude large animals such as sea turtles, stingrays, sharks, sponges *etc.* BRDs can have other benefits such as improving the quality of the catch, reducing at sea workloads and sometimes increasing the prawn catch. BRDs can be broadly classified into three categories based on the type of materials used for their construction, as Hard BRDs, Soft BRDs and Combination BRDs. Hard BRDs are those, which use hard / semi flexible grids as separating devices in their construction (DeLancy *et al.*, 1997).
There are four main advantages in reducing the amount of unwanted bycatch taken in shrimp trawls (Brewer et al., 1998; Salini et al., 2000; Anon, 2004b; Pravin et al., 2011).

1) It reduces the impact of trawling on the marine community, including deaths to vulnerable or endangered species. 2) Fishers could benefit economically from (a) Higher catch values (b) Reduction in large bycatch species which damage the shrimp caught (c) Shorter sorting time (d) Lower fuel costs due to reduced net drag (e) Longer tow times since the cod end would fill more slowly. 3) Fishers would hear less criticism from community groups. 4) Recreational and non-shrimp commercial fisheries would benefit from a reduced impact on species of their concern.

Use of BRDs in certain areas helped in the recovery of certain endangered species (Garcia-Caudillo et al., 2000). The significance of BRDs has been mentioned by various fishery institutions, fishery scientists, fishermen and fishery managers. About 25-64% of bycatch can be reduced without compromising the target catches by the incorporation of BRDs in fishing gears especially in trawl nets (Bjordal, 1999; Gallaway and Cole, 1999; Salini et al., 2000; Burrage, 2004; Hall and Mainprize, 2005).

Trawl operations adopting CIFT-TED in Arabian Sea and Bay of Bengal indicated 100% exclusion of sea turtles with a mean catch loss in range of 0.52 to 0.97% for shrimp and 2.44 to 3.27% for non-shrimp resources (Anon, 2003b; Bopendranath et al., 2003). The loss is substantially less than the loss incurred during the operations with imported TED devices (Bopendranath et al., 2003).

Most BRDs are located in the codend of the trawl as this is where the catch is accumulated and the opportunity to escape is high. BRD are of two categories depending on the principle method used to exclude bycatch from the trawl. The first category is BRDs
that separate the catch by size. These devices use inclined grids or panels of netting to physically block the passage of bycatch into the codend and guide it toward an escape opening. Depending on their design, these devices exclude bycatch from the trawl. The grid-style juvenile and trash excluder device (JTED) and square-mesh codend are examples of BRDs that exclude small animals from the trawl. TEDs can also be included in this category because they exclude large bycatch animals from the trawl. The second category of BRDs is those that exploit behavioural differences between shrimp and bycatch. Most fish can swim in a moving net, orient to the direction of tow, and swim out through an escape opening. This behaviour is principally the result of fish responding to the visual stimulus of the trawl and the generation of water turbulence as the trawl is towed through the water. Shrimp, on the other hand, generally exhibit little directional swimming and passively enter the codend. They respond principally to tactile stimuli (touch) and have limited capability to swim in a moving trawl and through an escape opening. Examples of this type of BRD are the fisheye, square-mesh window and Jones-Davis BRD (Eayrs, 2007).

Since juveniles contributing 40% to the bycatch in India a Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) has been developed for bringing down the bycatch of juveniles and small sized non-targeted species in commercial shrimp trawl (Boopendranath et al., 2008). The JFE-SSD operations off Cochin, India had relaised bycatch reduction up to 43% with shrimp retention of 96-97% (Boopendranath, 2009).

Ganga et al. (2014) opined that the Code of Conduct for Responsible Fisheries (CCRF) spells out that while the aim of maximizing returns are pursued by the fishermen it should be done without adversely affecting the self-sustaining nature of the fishery resources and with least impact on the ecosystem. The Central Marine Fisheries Research
Institute (CMFRI) and Central Institute of Fisheries Technology (CIFT) have suggested following ecofriendly approaches to ensure long term sustainability of the fishery sector:

- Use square meshed trawl nets with 35 mm codend which minimizes juvenile fish catch.
- Avoid use of engines with high Horse Power (HP) (> 250 HP) and restrict maximum engine power in trawls as per craft dimensions (crafts up to 15m Over All Length (OAL) - 140 HP, 15 - 17.5 m OAL - 200 HP and 17.5 - 20 m OAL - 250 HP).
- Adopt Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) in trawls which have an *in situ* sorting effect (by-catch reduction up to 43%, and shrimp retention of 95% with capacity to exclude jellyfish).
- Use only >22 mm mesh seine nets for pelagic fishes like oil sardine and mackerel.
- Voluntarily avoid catching of juvenile fish shoals during fishing activity using seine nets.
III. MATERIALS AND METHODS

The details of research methods and procedures followed to carry out the present study are delineated in this chapter.

3.1 Site selection

Mangalore fishing harbour (Lat. 12°50'54"N; Long. 74°50'11"E, Plate 1) is one of the major landing centres of coastal Karnataka, contributing more than 40 percent to the total marine fish landings of the state. The sampling station was selected to represent variability in fishing grounds, species diversity, fishing methods and landings of trash fish from trawlers.

3.2 Sampling methods and data collection

Number of trawlers operating along Karnataka are 2862 among them 1740 are single day trawlers and 1122 multiday trawlers (Anon, 2012a) of which 1050 trawlers are operated from Mangalore fishing harbour (Anon, 2010b). The data on commercial fish landing and trash fish landing were collected from the trawl landings at Mangalore fisheries harbor during the fishing seasons for the years 2012-13 and 2013-14. The fish catch data viz. total quantity of fish landed, low value bycatch (trash fish) contribution and other fishing information on both single day and multiday trawlers were collected from 10% of the total number of trawl boats for 16 days in a month by employing the stratified random sampling design developed by CMFRI. Monthly estimates of catch and species composition of trash fish were prepared based on data collected (Srinath et al., 2005).

Generally multiday trawlers engaged in fishing for 8 to 10 days in a trip and a day break for unloading and ice filling between the cruises i.e. almost three trips per month. Hence an unsorted portion of LVB (trash) samples preserved in ice were collected thrice
in a month and brought to the laboratory to identify the fishes up to species level. Qualitative and quantitative analysis of the samples were carried out in the laboratory. Weight of the sample was recorded and the species present in the sample were sorted out. The number, total length and weight of individual finfishes in each group were recorded. The number was raised to the month’s finfish trash catch.

### 3.3 Identification of finfish species

The unsorted LVB (trash) sample were sorted out and finfish portion was identified up to species level following FAO identification sheets (Fischer and Bianchi, 1984); Fish Base (http://fishbase.org) (Froese and Pauly, 2011); ITIS (Integrated Taxonomic Information System) standard report (http://www.itis.gov); WoRMS (World Register of Marine Species) (http://www.marinespecies.org) (Appeltans et al., 2011).

### 3.4 Quantification of finfish landed as LVB, number and their percentage composition in weight and number

Month wise finfish length range, number of individual species and weight of individual species was recorded and summation done for the respective years. Total quantity of individual finfish landed as LVB (trash) species and their percentage composition in weight and number was calculated by following formulas (Dineshbabu et al., 2012; Personal communication).

\[
\text{Projected weight of individual species} = \frac{\text{Weight of individual finfish species in LVB sample}}{\text{Total weight of finfish sample}} \times \frac{\text{Projected weight of finfish LVB of respective year}}{}
\]

\[
\% \text{ weight} = \frac{\text{Weight of individual species in the sample}}{\text{Total weight of finfish sample}} \times 100
\]
% number = \frac{\text{Number of individual species in the sample}}{\text{Total number of finfish in sample}} \times 100

3.5 Percentage of juveniles of commercially important finfish species

Commercial species of finfish recorded in the trash fish sample were sorted out and the Minimum Size at Maturity (MSM) was considered for segregation of juveniles from the adults (Hubbs, 1943). Total number of juveniles of individual species was noted down and average weight of individual species was recorded. The percentage of juveniles of commercially important finfish species in number and weight recorded from LVB (trash) landings was calculated using following formulas (Dineshbabu et al., 2012; Personal communication).

Average weight = \frac{\text{Total weight of Individual species}}{\text{Total number of specimens of individual species}}

% number of juveniles = \frac{\text{Juvenile number of individual species in the sample}}{\text{Total number of finfish specimens in the sample}} \times 100

\text{Juvenile weight of individual species} = \frac{\text{Juvenile number of individual species in the sample}}{\text{Average weight of individual species}} \times \text{Average weight of individual species}

% Juvenile weight of individual species = \frac{\text{Total juvenile weight of individual species}}{\text{Total weight of finfish LVB}} \times 100
3.6 Estimation of resource damage to commercially important finfish resources

To know the impact of the landing of commercially important finfish juveniles in trash fish, resource damage to individual commercial species was estimated by calculating projected number of juveniles and their weight landed as LVB using following formulas (Dineshbabu et al., 2012; Personal communication).

\[
\text{Projected juvenile number of individual species} = \frac{\text{Juvenile number of individual species in the sample}}{\text{Total weight of finfish LVB sample}} \times \text{Projected weight of finfish LVB of respective year}
\]

\[
\text{Projected juvenile weight of individual species} = \frac{\text{Projected juvenile number of individual species}}{\text{Average weight of individual species}} \times \text{Projected weight of finfish LVB of respective year}
\]
IV. RESULTS

Mangalore is the most important trawl landing centre in Karnataka and one of the most progressive fisheries harbour in the country. Present study revealed that during 2012-2014 period, most of the trawling operations are concentrated within the 180 m depth zone and extension was mainly parallel to the shore, towards south or north.

4.1 Profile of trawl landings

4.1.1 Landings of commercial fishes and low value bycatch (trash) by single day trawlers (SDT)

Single day trawlers generally start their voyage in the month of October or November and operate in waters up to 30 meter depth and entire catch is brought to shore, which is separated as commercial catch and the rest as low value bycatch termed as trash. The landings of SDT at Mangalore during the fishing season of 2012-13 was 2,238.8 t, of which 1,501.44 t (67%) was of edible grade and 737.36 (33%) was LVB (Table 1 & Fig. 1). It was estimated that during fishing season of 2013-14, out of 2,063.46 t landed, the composition was 1,158.08 t (56%) and 905.38 t (44%) respectively (Table 1 & Fig. 2).

Seasonal trends in landing of LVB by single day operating trawlers revealed that the commercial landings increased during post monsoon months and the highest landings were recorded in the month of March for the fishing seasons. From the results the highest trash landings was observed in March 2014 (165.20 t) followed by January 2014 (157.27 t), February 2014 (149.41 t), February 2013 (138.64 t) and November 2013 (120.37 t). Meanwhile the lowest landings of LVB recorded in Oct. 2012 (4.03 t), followed by May 2013 (75.49 t) May 2014 (83.19 t), March 2013 (83.57 t) and April 2013 (102.38 t) (Table 2 & Fig. 3).
4.1.2 Landings of commercial fishes and low value bycatch (trash) by multiday trawlers (MDT)

The total quantity landed by MDT was estimated as 1,71,151.02 t in 2012-13, out of which 1,39,461.77 t (81%) was landed for edible purpose and 31,689.25 t (19%) was landed as trash (Table 1 & Fig. 5). In 2013-14, landing reduced to 1,60,683.38 t out of which only 1,24,734.24 t (78%) were landed for edible purpose and 35,949.14 t (22%) were landed as LVB (trash) (Table 1 & Fig. 6).

The seasonal trends in landing of LVB by multiday trawlers indicated that, highest quantity of commercial catches were recorded in the beginning months of fishing season for both years, thereafter the catches declined throughout the year. The maximum LVB landing was recorded in May 2013 (5,270.27 t) followed by April 2014 (5,184.72 t), May 2014 (4,847.17 t), March 2014 (4,613.91 t) and February 2014 (4,228.47 t). The lowest landing of LVB was recorded in August 2013 (169.38 t) followed by August 2012 (218.32 t), December 2012 (2,421.67 t), November 2012 (2,759.01 t) and December 2013 (2853.49 t) (Table 2 & Fig. 7).

Major groups and their percentage composition of LVB (trash) landed by MDT during study period revealed that finfish (87%) were the dominant group landed as LVB with contribution of 86.25% during 2012-13 and 88.34% in 2013-14 (Table 4).
Cephalopods were next to finfish which contributed on an average 8 per cent and Crustaceans (3%), Bivalves (1%) and Gastropods (1%) contribution was meagre to the trash landings (Fig. 8).

4.1.3 Quantification of LVB landings by trawlers at Mangalore

The trawl catch estimated at Mangalore during the fishing season of 2012-13 was 1.73 lakh t out of which 1.40 lakh t (81%) was retained for commercial purpose and 0.32 lakh t (19%) was LVB (trash) (Table 1 & Fig. 9). In 2013-14 the total fish landings by trawlers reduced to 1.62 lakh t of which only 1.25 lakh t (77%) were landed for edible purpose and the LVB increased to 0.36 lakh t (23%) (Table 1 & Fig. 10).

Monthly variation of trash landings showed that maximum LVB landing was recorded in May 2013 (5,345.77 t) followed by Apr. 2014(5,297.19 t), May 2014 (4,930.36 t), March 2014 (4779.10 t) and February 2014 (4377.89 t). Whereas the lowest landing of LVB was recorded in August 2013 (169.38 t) followed by Aug 2012 (218.32 t) and December 2012 (2,532.23 t) (Table 2 & Fig. 11). It clearly depicted that the trash landings was more during Pre monsoon months followed by Post monsoon months. During monsoon months LVB landings were comparatively less as demand for trash is comparatively low because of erratic weather conditions and availability of huge catch of commercially important fishes immediately after monsoon ban.

The results of monthly variation in percentage contribution of commercial catch and LVB landings revealed that the highest contribution of LVB to the total landings was recorded during the month of November 2013 with 28.80 per cent, which declined to 28.73 per cent in the month of April 2014 and 28.31 per cent in the month of March 2014. On the other side the lowest per cent contribution was recorded in August 2012 (10.73%)
followed by October 2013 (12.76%) and September 2012 (12.94%). It was observed that while the percentage of commercial landings was reduced, the landing of LVB increased substantially and vice versa (Fig. 12).

4.2 Profile of trawl LVB finfish composition

A total 121 finfish species belonging to 82 genera, 55 families and 13 orders were recorded in LVB landed by MDT during study period from August 2012 to May 2014. Order Perciformes was the most diversified group having 74 fish species (61.16%) followed by Clupeiformes with 13 species (10.74%), Aulopiformes and Scorpaeniformes, 6 species each (4.96%) to the total finfish species (Table 5 & Fig. 13).

4.2.1 Family wise percentage number composition

121 finfish species belonging to 55 families were recorded in MDT during study period. Family Carangidae contributed 11.57 percent (14 species) to the total number of species, followed by Engraulidae and Leiognathidae with 6.61% each (8 species each), Synodontidae with 4.96 per cent (6 species), Sciaenidae with 4.13 per cent (5 species), Nemipteridae and Scombridae with 3.31 per cent each (4 species), Clupeidae, Mullidae, Lutjanidae, Serranidae, Sphyraenidae, Terapontidae, Scorpaenidae and Ariidae with 2.48 per cent each (3 species each) to the total fish species, whereas other families contributed 40 per cent (Table 5 & Fig. 14).

4.2.2 Order wise percentage number composition

A total 121 finfish species belonging to 13 orders were recorded in MDT during study period. The order Perciformes contributed 61.16 per cent (74 species) to the total number of species, followed by Clupeiformes with 10.74% (13 species), Aulopiformes and Scorpaeniformes with 4.96% each (6 species each), Pleuronectiformes, Siluriformes and
Tetraodontiformes with 3.31 per cent each (4 species each), Anguilliformes and Lophiiformes with 2.48% each (3 species each) to the total fish species, whereas other orders together contributed less than 4 per cent with the presence of single species each (Fig. 13).

4.3 Quantification of Low Value Bycatch

4.3.1 Species wise quantity and percentage contribution landed as LVB by multiday trawlers

Details of the species and their catch composition, and percentage contribution for the study period are presented in Table 6 and Fig. 15.

*Lagocephalus inermis* contributed 6,788.40 t to the total finfish LVB landings with 23% of weight followed by *Decapterus russelli* with 5,347.22 t (18%), *Trichiurus lepturus* with 1,978.70 t (7%), *Rastrelliger kanagurta* with 1,931.29 t (nearly 7%), *Dussumieria acuta* with 1,734.31 t (6%), *Saurida tumbil* with 1,429.51 t (5%), *Mene maculate* with 1,099.13 t (4%), *Muraenesox* sp. with 715.32 t, *Platyecephalus indicus* with 712.12 t, *Encrasicholina devisi* with 697.07 t, *Sardinella longiceps* with 657 t, *Uranoscopus* spp. with 644.96 t (approximately 2% each) and all other species together formed 20 per cent of the total finfish LVB landings.

4.3.2 Species wise number and percentage contribution to the landings of LVB by multiday trawlers

Results of percentage number contribution by finfishes during the study period revealed that *Decapterus russelli* was the most dominant species which contributed 16.16% to the total number of fish landed followed by *Lagocephalus inermis* (14.32%), *Rastrelliger kanagurta* (8.42%), *Saurida tumbil* (7.57%), *Photopectoralis bindus*
Encrasicholina devisi (6.46%), Platycephalus indicus (4.75%), Nemipterus randalli (4.62%), Trichiurus lepturus (4.03%), Sardinella longiceps (3.05%), Dussumieria acuta (2.30%), Leiognathus sp. (2.16%), Mene maculata (1.54%), Fistularia petimba (1.27%), Terapon spp. (1.25%), Epinephelus diacanthus (1.24%), Apogon sp. (1.21%), Muraenesox sp. (1.11%), Sardinella spp. (1.05%), whereas all other species contributed approximately 10 percent to the total number of finfish species landed (Table 7 & Fig. 16).

### 4.4 Percentage of juveniles of commercially important finfishes in trash fish

During the study period it was observed that finfishes landed as LVB were both non-commercial and commercial species. Among commercial species the criteria was smaller size. To find out the percentage composition of commercially important finfish juveniles in trash landings, minimum size at maturity was used for juvenile segregation. During study period it was noticed that on an average 47.53 per cent of the finfish LVB landings were contributed by juveniles of commercially important species and in terms of number they formed 56.1 per cent. In 2012-13 the juveniles contributed 46.56 per cent of the landings and 55.64 per cent of the number. In 2013-14 the contribution was 46.92 per cent and 56.51 per cent respectively (Table 8).

From the fisheries sustainability point of view, resource loss in terms of number is more important than the weight, since maximum portion of the LVB were juveniles which form the backbone of the fishery for future. Juveniles of Decapterus russelli placed in a top position by contributing on an average 13.9 per cent to the number and 15.89 per cent to the weight followed by Saurida tumbil (7.39 & 4.72%), Rastrelliger kanagurta (7.29% & 5.66%), Photopectoralis bindus (6.31% & 1.14%), Platyccephalus indicus (4.75% & 2.49%), Nemipterus randalli (4.60% & 1.15%), Trichiurus lepturus (2.48% & 4.79%),
Sardinella longiceps (2.35% & 1.75%), Epinephelus diacanthus (1.23% & 1.26%), Mene maculata (0.99% & 2.56%), Muraenesox spp. (0.95% & 2.06%) and all other juveniles of commercially important species formed 3.86 per cent to the number and 4.06 per cent to the weight of finfish LVB landings of the study period (Table 8).

**4.5 Impact of the landing of commercially important finfish juveniles in trash fish**

Impact of the landing of commercially important juveniles in trash fish landing can be assessed by estimating the resource damage due to landing of juveniles as LVB and discarding over the sea. Trash fish comprised almost all the commercially important species ranging from shrimps, cephalopods, demersal fishes and also juveniles of pelagic fishes. The quantity of finfish LVB estimated for Mangalore Fisheries Harbour for the study period was on an average 29,547 t per year. Among that, juveniles of commercially important finfishes formed 14,044 t. The resource damage to the commercially important species, is mainly affected by juvenile loss in terms of number than in terms of weight. Hence it is estimated that these juveniles formed 1,100 million in numbers.

During the study period on an average about 272.4 million number of Decapterus russelli juveniles was landed as trash per year and the weight estimated was 4,693.4 t. In the case of Saurida tumbil the quantity landed in number and weight were 144.9 million and 1,395.7 t per year respectively. Rastrelliger kanagurta which is one of the dominant pelagic fish resources of the south-west coast landed 142.9 million number per year and the weight estimated was 1,671.4 t. Similarly other species such as Photopectoralis bindus (123.7 million & 336.2 t), Platycephalus indicus (93.1 million & 737 t), Nemipterus randalli (90.1 million & 338.3 t), Trichiurus lepturus (48.5 million & 1,416.6 t), Sardinella longiceps (46 million & 515.9 t), Epinephelus diacanthus (24.2 million & 373.5 t), Mene maculata (19.4 million & 756.5 t), Muraenesox spp.
(18.5 million & 609.8 t), Encrasicholina devisi (10.9 million & 63.1 t) and other juveniles of commercially important species (64.7 million number and 1,136.6 t) contributed in number and weight per year respectively to the LVB landings (Table 9).
V. DISCUSSION

5.1 Quantification of low value bycatch at Mangalore

The LVB landings formed on an average 21.5% of the trawl catch during study period with the contribution of 0.32 lakh t (19%) in 2012-13 and 0.36 lakh t (23%) during 2013-14. The average LVB to target group ratio during 2012-14 was 1 : 3.88. Monthly variation of trash landings showed that maximum LVB landing was recorded in May 2013 (5,345.77 t) followed by Apr. 2014 (5,297.19 t). Results of present study represented high landings of LVB during pre-monsoon months followed by post monsoon months than monsoon months.

In tropical countries like India, bycatch issue is more complex due to the multi-species nature of the fisheries. The observations of preliminary assessment of bycatch and discards in India revealed that 79.18% of total shrimp trawl landings were bycatch (George *et al*., 1981). According to Alverson *et al.* (1994) the shrimp trawling contributed 37.2% of bycatch worldwide with an annual bycatch of 28.7 mt of which an estimated 27.0 mt were discarded. Sukumaran *et al.* (1982) estimated 85% of the trawl landings as bycatch off Mangalore and Malpe in Karnataka during 1980-82. It was observed by Rao (1988) that the quantity of bycatch discarded in Visakhapatnam (India) depends on the demand for finfishes in the external and domestic market. Menon *et al.* (2000) revealed that the ratio of target : bycatch along the southwest and southeast regions of India were 1 : 4.6 and 1 : 1.26 respectively. Jayaraman (2004) estimated trash fish to constitute 10-20% of total catches landed by trawlers operating along the Indian coast in 2003.
The demand for targeted resources has paved way for indiscriminate bottom trawling along the coast with an ultimate result of massive wastage of low value, high volume bycatch including a wide spectrum of non-edible benthic biota. Kelleher (2004) has estimated 20.3% of bycatch discards in Indian fisheries. Bycatch formed 54% and 48% of total trawl catch during the years 2001 and 2002 in bottom trawling along Karnataka coast. The quantity discarded was 34,958 t (33.9%) in 2001 and 38,318 t (35.1% of total catch) in 2002 (Zacharia et al., 2006).

Single day trawlers are generally operated in inshore waters, up to 30 meter depth and bring entire catch to the shore. Hence the proportion of LVB is more than multiday trawlers. The landing of LVB from SDT at Mangalore during the fishing season of 2012-13 was 33% (737.36 t) and during 2013-14 fishing season it was 44% (905.38 t). LVB to target group ratio for SDT landings during 2012-14 was on an average 1 : 1.66. The catch per unit effort (CPUE) for single day trawler LVB landings varied from 573 kg in March 2014 to 93 kg in October 2012 with an average landing of 376 kg for the study period (Table 10). Multiday trawlers generally operate up to 180 meter depth and in earlier days they use to bring LVB of last two to three days, but in present days the trend has changed due to high demand for LVB from fish meal and poultry feed industries. Hence boats of high fish hold capacity are bringing as much as LVB according to availability of commercial catch during fishing trip. The total quantity of LVB landed by MDT was estimated as 19% (31,689.25 t) for the fishing season of 2012-13 and 22% (35,949.14 t) for 2013-14. However the LVB to target group ratio was 1 : 3.93 for MDT landings during 2012-14. The CPUE for LVB landings by MDT varied from as high as 4.85 t in May 2013 to 0.57 t in August 2013 with an average landing of 2.52 t for the study period (Table 10). Considerable quantity of landings of LVB during the months of September
(Avg. 3,327.69 t), October (Avg. 3,583.9 t) and November (Avg. 3,372.23 t) months shows the changed trends in LVB utilization in Mangalore fisheries harbour. However, with the dwindling returns from the trawlers these trawlers have no options other than increase the utilization of LVB. Landing of LVB also helps to manage financial crisis during lesser catch of commercial fishes to partly meet the expenditure of fuel by fetching Rs. 8/kg during post monsoon months to Rs. 16/kg during pre-monsoon months.

Zacharia et al. (2006) assessed the bycatch and discards associated with bottom trawling along Karnataka coast. The bycatch landed from SDT was 52.3% in 2001 and 60.2% 2002. Muliday trawlers contributed 52.3% as LVB in 2001 and 51.75% during 2002. About 30% of total catch from MDT was discarded whereas it was about 44% from SDT. During the year 2007-2008 a total 1,601 t of fishes landed by single day trawlers operated from Mangalore. Out of which 36.44% were of non edible low valued fauna (trash). The highest trash landed during December (47.2%). Multiday trawlers landed 65,589 t, of fishes out of which 3.69% were landed as trash, which formed part of the bycatch caught during the last two days of the fishing. The low valued bycatch caught earlier to the last two days were discarded due to lack of space (Dineshbabu et al., 2010).

Dineshbabu et al. (2012) reported that, the LVB landing of SDT at Mangalore in 2008 was 26% of the total landings, whereas in 2009 the LVB composition was 47%. In 2008, a total of 1,00,002 t of fishes were landed by MDT out of which 98% were considered as edible and rest was trash. During the year 2009, fish landing reduced to 83,148 t out of which only 83% were landed as edible and remaining 17% were landed as LVB (trash). The LVB landing increased from 15.3% of total landing in 2009 (14,837 t) to 25.4% in 2010 (25,678 t) at Mangalore fisheries harbor. The high demand for trash fish had been the major reason for increased LVB landing. In single day trawlers, 40% of the
catch was landed as trash, which was dominated by stomatopods. Landing of low value bycatch showed an increasing trend i.e. 16.7% at Calicut and nearly 27.4% at Visakhapatnam. Low value bycatch formed 15% of the total trawl landing in Chennai and in Versova, Mumbai the LVB formed 39% of total catch (Anon., 2011b).

According to Manojkumar and Pavithran (2012) the estimated LVB trawl catch at Calicut for the period 2007-2011 varied from 9,116 t (2009) to 14,118 t (2007) and average for the period was 12,241 t. The monthly contribution of low value bycatch ranged between 730 t (August) and 1,716 t (May). Dineshbabu et al. (2014) observed that there was a phenomenal increase in landings of LVB landings at Mangalore fisheries harbour as well as in other major landing centres of the country. The trash fish landing at Mangalore rose from only 3% in 2008 to 26% of trawl catch landed in 2011. This increase in trash landings was due to increased demand from an array of fish meal plants operating all along the Karnataka coast. Decline in oil sardine landings resulted in a crisis of raw material to meet the demand for fishmeal. Trash fish provided a viable alternative for fish meal production. Along the west-coast of India, most of the bycatch landed were utilized for fishmeal and manure production (Zynudheen et al., 2004; Kumar and Deepthi, 2006; Dineshbabu, 2011). Hence the results of LVB landings are comparable with those reported by Alverson et al., 1994; Jayaraman, 2004; Kelleher, 2004; Zacharia et al., 2006; Dineshbabu et al., 2010, 2012, 2014 and Anon., 2011b).

5.1.1 Seasonal variation in LVB landings

Monthly contribution of low value bycatch ranged between 169.38 t (August, 2013) and 5,343.77 t (May, 2013). Observation of monthly variation of trash landings from trawlers during study period showed that maximum LVB landing was recorded in May 2013 (5,345.77 t) followed by April 2014 (5,297.19 t), May 2014 (4,930.36 t), March 2014
Seasonal trends in landing of LVB by single day operating trawlers showed that highest trash fish landings was observed in March 2014 (165.20 t) followed by January 2014 (157.27 t), February 2014 (149.41 t), February 2013 (138.64 t) and Nov. 2013 (120.37 t). In case of multiday trawlers, maximum LVB landing was recorded in May 2013 (5,270.27 t) followed by April 2014 (5,184.72 t), May 2014 (4,847.17 t), March 2014 (4,613.91 t) and February 2014 (4,228.47 t). Results of present study depicted highest landings of LVB during pre-monsoon months when the conditions are favourable for fish drying and the demand for trash was maximum, followed by post monsoon months than monsoon months.

Zacharia et al. (2006) in their study on assessment of bycatch and discards associated with bottom trawling along Karnataka coast, India opined that the maximum bycatch was recorded in March followed by May in multiday trawlers in 2002 and the discards were more in post-monsoon months than other months. Dineshbabu et al. (2010) recorded the highest trash fish landings in Mangalore during December 2007. The low valued bycatch caught earlier to the last two days were discarded due to lack of space and it was estimated that 14% of the catch was discarded during the process.

In Mangalore it was observed that highest landing of trash fish was observed during pre-monsoon months of 2008-2009, when conditions are favourable for fish drying and the demand for trash was maximum. During these months it was noticed that the discard percentage was lowest and during rainy and post-monsoon seasons, the discard percentage was more than those landed as trash (Dineshbabu et al., 2012). Manojkumar and Pavithran (2012) reported that the monthly contribution of low value bycatch ranged between 730 t (August) and 1,716 t (May). Dineshbabu et al. (2014) also found though most of the LVB landed during the study period was due to existence of very efficient chain for LVB at
Veraval, on board participatory studies conducted during 2011 showed that there was an increase in discards (10.44%) during the monsoon months (August to December) due to reduction in demand for the trash fish because of erratic weather conditions. The results of present study agree with these of above studies.

5.1.2 Components of LVB (trash)

In SDT stomatopods are the major components of LVB, contributed on an average 61% during the study period. Gastropods and crabs (15% each) contributed substantially to the LVB, whereas finfish (8%) and cephalopods (1%) were the least contributors to the LVB during the study period. Major groups landed by MDT during study period showed that finfish were the dominant group landed as LVB with contribution of 87% on an average, during study period followed by Cephalopods (8%) and Crustaceans (3%), Bivalves (1%) and Gastropods (1%) contributed least to the trash landings. The results of present study are in line of following studies.

Kurup et al. (1987) noted that the annual bycatch in trawl fishery of Karnataka was 85% of the total trawl catch and stomatopods were the major constituent of bycatch. Menon (1996) studied impact of bottom trawling on exploited resources along the southern region of Karnataka, Kerala and Tamil Nadu during 1985-90. He found that target groups such as shrimp and cephalopods together constituted only 20% and others such as finfishes and benthic organisms constituted the rest of the trawl landings. The quantity of bycatch landed by trawlers in the above states during 1985-90, was estimated to be 43,000 t, of which 81% was accounted by stomatopods.

In a country like India where marine fishery consist of multispecies composition, the occurrence of by-catch consisting of several species of fish is bound to happen,
especially for the trawler operators with regard to on-board handling, preservation, storage, processing and marketing. The characterization and quantification of bycatch and discards along Kerala coast was studied by Kurup et al. (2003). The study revealed that the dominant varieties among the discards were finfishes, crabs and stomatopods. The group wise average discards during 2000-2002 showed that finfishes (95,000 t) were the major components, followed by crabs (68,000 t), stomatopods (40,000 t), gastropods (22,000 t), juvenile shrimps (5,000 t), soles (3,000 t), jelly fishes (3,000 t), cephalopods (2,900 t), echinoderms (1,800 t), sea snakes (1,000 t), and eggs (890 t). Squilla, though doesn’t have economical value, has significant ecological importance as it forms one of the food item of a large number of demersal organisms (Mohamed, 2004).

Bycatch and discards associated with bottom trawling along Karnataka coast was studied by Zacharia et al. (2006). They opined that the most dominant group among bycatch was stomatopods (39%) in SDT, followed by finfishes (36%). In MDT finfishes were the dominant group (69%). Dineshbabu et al. (2010) also found that during the year 2007-2008 the bycatch of trawl boats in Mangalore was predominated by stomatopods followed by finfishes, whereas, nonedible crabs, other invertebrates, cephalopods and other molluscs were present in lesser quantities.

From the results of present study it is clear that composition of the LVB matters the value realization for trash. Finfish dominated LVB fetched as high as Rs. 16/kg during summer months. LVB landed by single day trawlers mainly consisted of stomatopods and gastropods and fetched only Rs. 6/kg due to less finfish composition. Dineshbabu et al. (2012) in their study on spatio-temporal analysis and impact assessment of trawl bycatch of Karnataka to suggest operation based fishery management options reported that, stomatopods were the major dominant components of LVB of single day trawlers, forming
63 per cent in 2008 and 43 per cent in 2009. Fin fishes like lizard fishes, puffer fishes, threadfin breams and flatheads were the major contributors to multiday trash. Fish which is sold for human consumption and as trash will be determined by the auction price for the fish. Even oil sardine and lesser sardines were also put along with the trash when the LVB auction prices crossed Rs. 10/kg.

Changing trends in bycatch utilization in peninsular India was studied by Dineshbabu et al. (2014). The study revealed that finfish was the major component of LVB landed by multiday trawlers in Mangalore and Calicut, and varied between 85 to 90 percent. Whereas in other centres like Veraval, Mumbai, Chennai and Visakhapatnam the finfish composition in LVB remained below 65 percent throughout the study period. The price for the LVB was determined by the composition of the LVB. Due to high finfish component in LVB though the maximum landings was observed in Veraval (50,000 t) the value realization was highest in Mangalore (Rs. 280 million). The trash fish was landed in semi preserved form by multiday trawlers fetched as high as Rs. 12/kg in Mangalore which was mainly used for fish meal preparation. Molluscs and crustaceans dominated LVB landed by single day trawlers fetched only Rs. 4/kg, which was mainly utilised for drying for low cost fishmeal. It was also observed that in summer period the value realized for the landed LVB gone up to Rs. 16/kg in Mangalore.

5.2 Profile of Trawl LVB finfish composition

From the sustainability point of view it is imperative to assess the species composition and the juvenile composition of LVB landings. A total 121 finfish species belonging to 82 genera, 55 families and 13 orders were recorded in LVB landed by MDT during the study period from Aug. 2012 to May 2014. Menon (1996) studied the impact of bottom trawling on exploited resources during the years 1985-90 along the southern region
of Karnataka, Kerala and Tamil Nadu states. According to his observations the discarded by-catch included many low-valued ground fishes (20 genera) including unmarketable juveniles of fishes, prawns, crabs and cephalopods. The post harvest loss of by-catch including juveniles of commercially important species and many taxa of benthic organisms might also seriously affect the coast-ward feeding migrations and predator-prey relationships of component species in the affected habitats.

Family Carangidae contributed 11.57 percent (14 species) to the total number of species, followed by Engraulidae and Leiognathidae (6.61% each), Synodontidae (4.96%), Sciaenidae (4.13%), Nemipteridae and Scombridae (3.31% each) were the major families. The order Perciformes contributed 61.16 per cent (74 species) followed by Clupeiformes (10.74%), Aulopiformes and Scorpaeniformes (4.96% each) and other orders. Sujatha (1995) in her study on finfish constituents of trawl bycatch off Vishakapatnam, found that 228 species from the discards belonging to 68 families were identified as a constituent of finfish bycatch landed by small trawlers based at Visakhapatnam. The bycatch constituted not only small-sized and non-edible species, but also juveniles of commercially important species. As per the observations of Pravin and Manohardoss (1996) on constituents of low value trawl by-catch a total of 87 species belonging to 42 families of finfishes constituted 82.7 per cent of the low value by-catch landed by mechanised trawlers operating off Veraval.

Though discarding of bycatch is practiced in the case of multiday trawling, its magnitude and species composition is not properly assessed. A comprehensive study that includes landed bycatch and at-sea discards will only reveal the complete picture of the impact on the biodiversity caused by the bottom trawling. Studies on the impact of bottom trawling on the ecology of fishing grounds and living resources of the Palk Bay and the
Gulf of Mannar showed the presence of 185 species in the bycatch, represented mainly by ground fish and stomatopods followed by other groups (Anon., 2002). The discards from bottom trawlers of Kerala coast, recorded by Kurup et al. (2003) represented mainly by epifaunal species and juveniles of commercially valuable species and the discards were represented by 103 species of finfishes, 65 gastropods followed by other groups. They observed that the high rate of discards from the Kerala is due to use of small codend mesh size of 18 mm against the statutory mesh size of 35 mm.

Zacharia et al. (2006) noticed that the discarded catch in MDT consisted of 53 species of fishes in that 23 were always discarded followed by 12 crustaceans during the years 2001 and 2002. In SDT, the discard comprised 35 species of fishes (10 always discarded). Juveniles of various groups formed an important bycatch of trawl fishery of Karnataka constituting about 15.9 % of the total catch in SDT and 23.5 % in MDT. Biodiversity of trawl bycatch in Kerala coast was studied by Bijukumar, (2008) who recorded 534 species associated with the trawl bycatch, which included 279 species of fishes.

Finfish constituted 87 per cent of the LVB landed by MDT during the present study period. Bijukumar and Deepthi (2009) noticed that the bycatch composition of trawl landings of Kerala coast constituted 217 species fishes in the trawl bycatch, classified under 21 orders, 88 families and 155 genera represented predominantly by demersal (79 species) and reef-associated forms (78 species). It was also observed that the dominant fraction of fish fauna (73%) of the trawl bycatch was represented by 159 species belonging to mid level carnivore category included in the trophic level 3.0-3.99. Presence of large
number of mid level carnivores in the trawl bycatch may indicate large scale removal of top level predators from the ecosystem.

During present study higher contribution of finfishes was noticed in the month of April (95.80%) followed by March (93.67%) and the lowest contribution was in August (73.72%). Manojkumar and Pavithran (2012) recorded 124 finfish species in the discards. Finfishes comprised mainly low value and juvenile fishes among the discards and it formed 63.15%, Higher contribution of fishes was noticed in February (86.18%) and lowest in November (29.2%). Dineshbabu et al. (2012) recorded a total of 123 species from trash landing of SDT at Mangalore during 2008-2009 while 198 species were identified from discard samples of MDT. Among the species recorded from multiday trawlers 116 species were finfishes and lizard fishes, puffer fishes, threadfin breams and flatheads were the major contributors. Juveniles of sharks and rays were also recorded.

Gibinkumar et al. (2012) identified 281 species in the trawl catch from the traditional trawling areas in coastal waters off Cochin, southwest coast of India. The bycatch included 191 species of fishes which belonged to 12 orders and 59 families and 109 genera. Dineshbabu et al. (2014) recorded a total 95 species of finfishes, 27 species of crustaceans and 20 species of molluscs from LVB landings at Mangalore during 2007-2011.

5.3 Species wise quantity, percentage contribution landed as LVB by multiday trawlers

The results of present study depicted that the species *Lagocephalus inermis* contributed 6,788.40 t to the total finfish LVB landings with 23% of weight followed by *Decapterus russelli* with 5,347.22 t (18%), *Trichiurus lepturus* with 1,978.70t (7%),
Rastrelliger kanagurta with 1,931.29 t (nearly 7%), Dussumieria acuta with 1,734.31 t (6%), Saurida tumbil with 1,429.51 t (6%), Mene maculata with 1,099.13 t (6%) were the major species contributed to LVB in terms of weight. During the study period it was observed that Decapterus russelli was the dominant species which contributed 16.16 per cent to the total number of finfish landed as LVB followed by Lagocephalus inermis (14.32%), Rastrelliger kanagurta (8.42%), Saurida tumbil (7.57%), Photoperctoralis bindus (6.97%), Encrasicholina devisi (6.46%) and other fish species.

Pravin and Manohardoss (1996) studied the constituents of low value trawl bycatch caught off veraval. According to their observations sciaenids were the major group found in LVB, contributed 15.6 per cent followed by engraulids (12.84%), ribbon fishes (8.9%), penaeid and non penaeid prawns (8.2%), squids and cuttle fishes (7.7%), polynemids (4.9%), white fish (4.2%), nemipterids (3.9%), leiognathids (3.3%), carangids (2.8%), flat fish (2.7%) and others (7.7%). Rest (17.3 %) were constituted by shells, jelly fish, squilla, crabs, sea snakes and unidentified groups. Zynudheen et al. (2004) noticed that, in Gujrath bulk quantity of low value bycatch landed for utilized for preparing fish meal and manure. The major groups constituted in trawl bycatches were sciaenids, engraulids, ribbon fish etc. Sciaenids contributed 15.6 percent of the catch, followed by engraulids (12.84%), ribbon fish (8.9%), squid and cuttle fish (7.7%). Other species included were polynemids (4.9%), Lactarius (4.2%), nemipterids (3.9%), leiognathids (3%), carangids (2.8%), flat fish (2.7%) and others like jelly fish, squilla, crabs, molluscs, etc.

The trash fish was sent to fish meal plants in Tamil Nadu, when large quantities were caught by trawlers, mostly comprising balistids, Decapterus and lizardfishes. Others commonly included with them were sciaenids, small-sized threadfin breams, crabs, and
species of *Fistularia, Holocentrus, Priacanthus, Scolopsis* and *Upeneus* (Joel and Ebenezer, 1996). The young / juvenile fish bycatch formed 5 to 15% of total catch in SDT and 5 to 28% in MDT landings at Mangalore - Malpe. Nemipterids, *Epinephelus* and lizard fishes were the major constituents in MDT, while flat fishes, silver bellies and sciaenids dominate in SDT (Anon., 2006b).

During study period *Lagocephalus inermis* formed 23% by weight to the LVB followed by *Decapterus russelli* (18%) and the species *D. russelli* was also the dominant species which contributed maximum (16.16%) by number to the total number of finfish landed as LVB followed by *Lagocephalus inermis* (14.32%). According to Dineshbabu et al. (2010) *Saurida tumbil* contributed a major portion to the bycatch by weight (12.5% among commercial species and 4.7% in the total discards) and *Photopectoralis bindus* contributed maximum (33% among commercial group and 21.1% among overall discards) by numbers in Mangalore fisheries harbour during 2007-08. Month- wise frequency of occurrence of species in the bycatch showed that *Platycephalus* sp. and *Saurida tumbil* were observed in most of the sampling days from September to June. Dineshbabu et al. (2012) reported that *Saurida* spp. contributed maximum to the LVB by weight (12.65%) in 2008 followed by *L. inermis* (11.2%) and during 2009 the species *L. inermis* formed highest constituent (13.6%) followed by *Nemipterus* spp. (11.4%) to the low value bycatch Mangalore fisheries harbour.

Bycatch and discards in commercial trawl fisheries of Malabar region was reported by Manojkumar and Pavithran (2012), who showed that the scads (20.57%) contributed highest to the low value bycatch landings followed by lizard fishes (14.88%), soles (14.23%), *Thryssa* spp. (4.29%), sciaenids (4.75%), other carangids (3.55%), silverbellies
(3.48%) and stomatopods (0.67%) in the low value bycatch landed by trawl catch at Calicut during 2007-2011. Finfish dominated trash was in much demand in Mangalore. During 2007-2012 the species *L. inermis* was the dominant portion of the bycatch and contributed 12.80% by weight to the LVB, followed by *Saurida* spp. (11.70%), *Decapterus* sp. (10.63%) *Sardinella longiceps* (8.59%) *Nemipterus* spp. (8.56%), lesser sardines (5.93%), *Platycephalus* sp. (4.06%) *Alepes* sp. (3.88%), *Rastrelliger kanagurta* (3.64%), *Dussumieria acuta* (3.49%), *Trichiurus lepturus* (3.41%) and other species (Dineshbabu *et al.*, 2014).

### 5.4 Resource damage due to landing of juveniles of commercial species in LVB

Mangalore fisheries harbor is one of the premier fisheries harbour, where juveniles of many commercial species are landed. Likewise the LVB landings also consisted enormous quantity of juveniles of many species. Among the commercial species, the criteria was smaller size. During study period it was observed that on an average 47.53 per cent of the finfish LVB landings were formed by juveniles of commercially important species and in terms of number they formed 56.1 per cent.

Sivasubramanyam (1990) observed that 50 per cent of the bycatch comprised of immature fish in trawlers from Bay of Bengal. As per the observations of Pillai (1998) 40 per cent of the catch from Indian seas was constituted by juveniles. Kurup *et al.* (2003) opined that the small cod end mesh of bottom trawlers exploited juveniles and sub-adults of commercial species in large quantities. In Karnataka, juveniles contributed 36 per cent of discards (15.9% of total catch) in single day fishing and 78 per cent (23.5% of total catch) in multi-day fishing during the years 2001 and 2002 (Zacharia *et al.*, 2006). In Mangalore fisheries harbor an estimated 63.7 per cent (by numbers) of bycatch was
constituted by juveniles of commercially important fishes during the year 2007-2008, causing significant damage to the stocks of these species. In terms of weight, commercial species constituted 37.4 per cent of total bycatch. Whereas in 2008-09 juveniles of commercial species formed 34 per cent of the discards and in terms of number they formed 44 per cent (Dineshbabu et al., 2010; 2012).

The quantity of commercially important finfish juveniles was estimated to be 14,044 t in LVB at Mangalore Fisheries Harbour for the present study period. Since the juveniles form back bone of fishery for future, it is imperative to know resource loss in terms of number than the weight to assess the sustainability of fish stocks. During the present study it was estimated that these juveniles formed 1,100 million in numbers. Menon (1996) reported that 6,200 t of juvenile fish and prawns were discarded back into the sea during 1980-84 along the south-west coast of India. Jayaraman (2004) estimated 1,549 t of the young / juvenile fish bycatch in SDT and 9,077 t in MDT formed 5 to 15 per cent of total catch (SDT) and 5 to 28 per cent (MDT) from the Mangalore - Malpe trawl landing base. Most of which were unmarketable and hence sold along with nonedible biota. It was observed by Zacharia et al. (2006) that, in Karnataka, annually 14,400 t of juveniles of finfishes, 2,448 t of shrimps, 1.673 t of cephalopods and 1,702 t of crabs besides 4,059 t of juveniles of other groups were removed by bottom trawling. The discards comprised almost all commercial species and juveniles of pelagic fishes. In 2008-2009 a total 37,533 t of discards were estimated for Mangalore Fisheries (Dineshbabu et al., 2012).

In the present study juveniles of Decapterus russelli was the dominant commercial resource that landed as LVB which is estimated to be on an average about 272.4 million
number of landed as trash per year and the weight estimated was 4,693.4 t. In the case of *Saurida tumbil* the quantity landed in number and weight were 144.9 million and 1,395.7 t per year respectively. *Rastrelliger kanagurta* which is one of the dominant pelagic fish resource of the south-west coast, landed with 142.9 million number per year and the weight estimated was 1,671.4 t and the juveniles of *Nemipterus randalli* which is one of the major demarsal resource of commercial landings of Mangalore landed 90.1 million in number and weight estimated was 338.3 t. Dineshbabu et al. (2009) reported that *Nemipterus mesoprion* in the trawling grounds of Karnataka for the fishing year 2007-2008 showed that only 30% (in terms of numbers) caught were landed as commercial catch and the rest (70%) was discarded as they were juveniles of low commercial value. During 2008-2009 juveniles of *Platycephalus sp.* landed about 2,733 t in discards of trawlers of Mangalore. The discarded number estimated was 464 million. *Nemipterus randalli*, one of the highest contributors to trawl landings at Mangalore also contributed considerably in the discards and the quantity discarded in weight and numbers were 1,341 t and 333 million respectively. Juveniles of high value resources like, seerfishes, cobia, cephalopods, shrimps, groupers and snappers were also found in substantial quantity and numbers in discards (Dineshbabu et al., 2012).

Generally it is understood that the bottom trawl fishing has been found to be most destructive method of resource exploitation in structurally complex and biodiversity-rich marine habitats that leads to community changes in benthos, reduction in biodiversity, biomass and size of organism (Jennings and Reynolds, 2000; Thrush and Dayton, 2002; Revil and Jennings, 2005). As in any tropical fishery, bycatch associated with trawling is a major component along the coast of India. Juvenile landing in LVB from Indian fisheries is having a heavy impact on marine trophic structure. Economic considerations play a major
role in the quantity of the bycatch landed and discarded. Trawlers equipped with advanced technologies in fishing and high storage capacity are intensively trawling to catch as much as possible without any concern over the size or the species of fish or the future concerns about the fishery. This practice resulted in heavy exploitation of juveniles of commercially important fishes and ecologically important biota. Bycatch landing by the trawlers is unavoidable in tropical multi-species scenario due to existence of trawling as back bone of Indian marine fisheries. Bycatch problem to a greater extent can be reasonably addressed by allowing trawling with nets with bigger codend mesh sizes, banning of trawling in certain seasons, effort reduction in critical fishing grounds and adoption of BRDs such as Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) can bring down the damages to the ecosystems by reducing juveniles in bycatch considerably.
VI. SUMMARY

Trawling is one of the most efficient methods of catching fish world over and is also the most important human caused physical disturbance to the world’s continental shelves, and consequently, the physical destruction of marine ecosystem. Trawl fishery is generally a mixed fishery targeting a number of species and sizes, simultaneously. As an active non selective fishing gear, trawl net collects every organism in its path and the incidental catch of non-target species called bycatch has become major concern allied to trawling. Bycatch not only includes non-commercial species, but also commercial species that are below minimum landing size (MLS) or less profitable species owing to market conditions. Hence there is need of regular assessment of bycatch and discards associated with bottom trawling to understand the extent of resource damage due to indiscriminate fishing and loss of commercially important juveniles.

The present investigation was taken up with objective to assess the Low Value Bycatch landings associated with bottom trawling from trawlers of Mangalore (Lat. 12°50'54"N; Long. 74°50'11"E), to characterize the finfish composition of low value by-catch generated from trawlers and to understand the extent of resource damage due to indiscriminate fishing and loss of commercially important juveniles. The data for the present study were collected from both single day and multiday trawl landings at Mangalore fisheries harbor during the fishing seasons for the years 2012-13 and 2013-14 by employing the stratified random sampling design developed by CMFRI. The salient findings of present investigations are summarised as follows.

1) The trawl catch estimated at Mangalore during the fishing season of 2012-14 was on an average 1.68 lakh t of fishes/year, of which 1.33 lakh t (79%) was retained
for edible purpose and 0.35 lakh t (21%) was marked as “low value by-catch” (LVB) mainly for fish meal production. The average LVB to target group ratio was 1 : 3.88. Seasonal trends in landing of trash showed that maximum LVB landing was recorded in May 2013 (5,345.77 t) followed by April 2014 (5,297.19 t). Whereas the lowest landing was recorded in August 2013 (169.38 t). From the results it is clear that the trash landings were more during Pre monsoon months followed by Post monsoon months. Considerable quantity landings of LVB during months of September, October and November showed the changed trends in LVB availability in Mangalore fisheries harbour.

2) Single day trawlers generally start their voyage in the month of October or November and operate in waters up to 30 meter depth and entire catch is brought to shore, which is separated as commercial catch and the rest as low value bycatch termed as trash. The landing of SDT for the study period was 2,151.3 t/year of which 1,329.76 t (61.8%) was of edible grade and 821.37 (38.2%) was LVB. LVB to target group ratio for SDT landings was on an average 1 : 1.66. Monthly variation in LVB landings revealed that the maximum LVB landing was recorded in March 2014 (165.20 t) followed by January 2014 (157.27 t) and the least landings of LVB recorded in October 2012 (4.03 t). The average CPUE for single day trawler LVB landings was 376 kg for the study period. Stomatopods were the major components of trash contributed on an average 61 per cent, whereas finfishes formed only 8 per cent of the trash landings.

3) Multiday trawlers generally operate up to 180 meter depth and trawlers are bringing as much as LVB according to availability of commercial catch during fishing trip. During the study period a total of 1,65,917.2 t/year fishes were landed by MDT out
of which 1,32,098 t (79.6%) were landed for edible purpose and remaining 33,819.2 t (20.4%) was landed as trash. However the LVB to target group ratio was 1 : 3.93 for MDT landings. Seasonal trends in LVB landings showed that the highest trash landings was noticed in the month of May 2013 (5,270.27 t) followed by April 2014 (5,184.72 t) and the lowest landings observed in August 2013 (169.38 t). The average CPUE for LVB landings by MDT was 2.52 t. Finfish were the dominant group landed as LVB with contribution of 87 per cent, followed by cephalopods which formed on an average 8 per cent during the study period.

4) A total 121 finfish species belonging to 82 genera, 55 families and 13 orders were recorded in LVB landed by MDT. Family Carangidae contributed 11.57 per cent (14 species) to the total number of species, followed by Engraulidae and Leiognathidae with 6.61% each (8 species). Order Perciformes was the most diversified group comprising of 74 species (61.16%) followed by Clupeiformes with 13 species (10.74%).

5) Results of percentage weight contribution by finfish species during the study period revealed that *Lagocephalus inermis* contributed 23 per cent of weight to the total finfish LVB landed by multiday trawlers followed by *Decapterus russelli* (18%), *Trichiurus lepturus* (7%), *Rastrelliger kanagurta* (nearly 7%), *Dussumieria acuta*, *Saurida tumbil* and *Mene maculata* (6% each), *Muraenesox* sp., *Platycephalus indicus*, *Encrasicholina devisi*, *Sardinella longiceps* and *Uranoscopus* spp. (approximately 2% each) and remaining species together formed 20 per cent of the finfish LVB landings.

6) The results of present study depicted that the species *Decapterus russelli* was the major species which contributed 16.16 per cent to the total number of fish landed as
LVB by multiday trawlers followed by *Lagocephalus inermis* (14.32%), *Rastrelliger kanagurta* (8.42%), *Saurida tumbil* (7.57%), *Photopectoralis bindus* (6.97%) *Encrasicholina devisi* (6.46%), *Platycephalus indicus* (4.75%), *Nemipterus randalli* (4.62%) and the rest of species together contributed nearly 31 per cent to the LVB landings.

7) During the study period it was observed that finfishes landed as LVB were both non-commercial and commercial species. To find out the percentage of composition of commercially important finfish juveniles in trash landings, minimum size at maturity was used as criteria for juvenile segregation. Juveniles of commercially important species contributed on an average 47.53 per cent of the finfish LVB landings and in terms of number they formed 56.1 per cent.

8) In the view of fisheries sustainability, loss in terms of number is more important than the weight, since the major portion of the LVB were usually juveniles which form the backbone of the fishery for the future. In the present study, juveniles of *Decapterus russelli* were the dominant commercial resource that landed as LVB which contributed on an average 13.9 per cent to the number and 15.89 per cent to the weight followed by *Saurida tumbil* (7.39% & 4.72%), *Rastrelliger kanagurta* (7.29% & 5.66%), *Photopectoralis bindus* (6.31% & 1.14%), *Platycephalus indicus* (4.75% & 2.49%), *Nemipterus randalli* (4.60% & 1.15%) and followed by other juveniles of commercially important species.

9) Resource damage due to landing of juveniles of commercial species in LVB was estimated to be 14,044 t/year and the number estimated was 1,100 million. About 4,693.4 t/year of *Decapterus russelli* juveniles were landed as LVB during the study period and the number estimated was 272.4 million followed by
Saurida tumbil which landed 1,395.7 t by weight and 144.9 million in number. Rastrelliger kanagurta which is one of the major pelagic fish resources of the south-west coast, landed 1,671.4 t/year and the number estimated was 142.9 million. In the case of Nemipterus randalli, which is one of the major contributors to trawl landings at Mangalore, the quantity of juveniles landed as LVB in weight and numbers were 338.3 t and 90.1 million/year respectively.

Since trawl fishery is the backbone of Indian marine fisheries bycatch is unavoidable in multi-species scenario. By-catch problem to a greater extent can be reasonably addressed by allowing trawling with nets with bigger mesh sizes, banning of trawling in certain seasons, effort reduction in critical fishing grounds and adoption of BRDs such as Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) can bring down the damages to the ecosystems by reducing juveniles in by-catch considerably.
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VIII. ABSTRACT

Trawling is one of the most efficient methods of catching fish world over and is also the most important human intervention causing physical disturbance to the continental shelves, and consequently, the physical destruction of ecosystems. Trawl fishery is generally a mixed fishery targeting a number of species and sizes, simultaneously. By-catch not only includes non-commercial species, but also commercial species that are below minimum legal size (MLS) or less profitable species owing to market conditions. Since the demand for fish meal is on the rise, more advanced technologies in fishing and vessel infrastructure are being introduced and practiced. These developments have resulted in heavy exploitation of juveniles of commercially important fishes and other ecologically important biota.

At Mangalore Fisheries Harbour, it was estimated that in 2012-14, trawlers landed on an average 1.68 lakh t of fishes per year, of which 1.33 lakh t (79%) was retained for edible purpose and 0.35 lakh t (21%) was marked as “low value by-catch” (LVB) mainly for fish meal production. For assessing the sustainability of marine fisheries production it is imperative to understand the species composition and the juvenile composition of the fishes in the LVB. From the LVB, 121 species of finfishes were recorded in MDT. Juveniles of commercially important finfish species formed 47.53 % of the finfish LVB by weight (56.1% by number). An estimated 4,693.4 t (272.4 million in number) of Decapterus russelli juveniles, 1,395.7 t (144.9 million in number) of Saurida tumbil and 1,671.4 t (142.9 million in number) of Rastrelliger kanagurta were landed as LVB per year by multiday trawlers. From the results it is evident that the trawlers equipped with advanced technologies in fishing and high storage capacity are intensively trawling to catch as much as possible without any concern over the size or
the species of fish or the sustainability of the fishery. Since trawl fishery is the backbone of Indian marine fisheries bycatch is unavoidable in multi-species scenario. Bycatch problem to a large extent can be reasonably addressed by allowing trawling with nets with bigger mesh sizes, banning of trawling in certain seasons, effort reduction in critical fishing grounds and adoption of BRDs such as Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) can bring down the damages to the ecosystems by reducing juveniles in by-catch considerably.