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# Characterization of low value bycatch in trawl fisheries off Karnataka coast, India and its impact on juveniles of commercially important fish species

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Trawl fishery is a mixed fishery targeting numerous species and sizes simultaneously, and therefore remains a controversial fishing method due to consequential catch of huge amount of non-targeted species. Along with non-commercial species, bycatch also includes commercial species that are below minimum legal size (MLS) or less profitable fishes owing to market conditions. Advanced technologies in fishing methods and fleet infrastructure are being introduced and practiced. Such developments have ensued in heavy exploitation of juveniles of commercially important fishes. Mangaluru fisheries harbour witnessed an average 168 thousand tonnes (t) of trawl landings/year in 2012-14, of which 133 thousand t (79 %) was retained for edible purpose and 0.35 thousand t (21 %) was marked as “low value bycatch” (LVB) which mainly transported as raw material for fish meal production. To assess the sustainability of marine fisheries production, it is important to understand the species composition and the juvenile composition of the fishes in LVB. A total of 121 species of finfishes were recorded from LVB of multiday trawlers (MDT). Among that, commercially important juveniles formed 47.5 % of the finfish LVB by weight (56.1 % by number). An estimated 4,693.4 t (272.4 million by numbers) of *Decapterus russelli* juveniles, 1,395.7 t (144.9 million by numbers) of *Saurida tumbil,* 1,671.4 t (142.9 million by numbers) of *Rastrelliger kanagurta* and 338.3 t (90.1 million by numbers) of *Nemipterus randalli* were landed as LVB per year by multiday trawlers. From the results it is evident that marine fisheries will be in serious threat in successive years if the similar trend continues. The study strongly advocates LVB management through adoption of Juvenile Fish Excluder-Shrimp Sorting Device (JFE-SSD) and reduced effort in critical fishing grounds would bring down the damages to the marine ecosystems.

**[Keywords:** Bycatch; Demand; Ecosystem damage; Juveniles; Trawl fisheries]

## Introduction

Fishing is one of the ancient occupations and recognized as a main source of income and employment generator 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 fishery provide a cheap source of animal protein to the people, especially for the weaker sections in the society, thereby it serves as a means to ensure the food security for millions of people, and in 2013 fish contributed about 17 % of animal protein supply[1]. According to Food and Agricultural Organisation (FAO), the total world fish production in 2014 was 167.2 million tonnes (mt), out of which marine capture fisheries contributed 81.5 mt (87.2 % to the world capture fisheries). A total of 20.9 mt of the world fish production were considered to be of non-food purpose[1]. Though trawling is known as one of the most efficient fishing methods world over it is also a prominent human caused physical disturbance to the world’s continental shelves resulting in the physical destruction of marine ecosystems[2,3]. Trawl gears are mainly operated from bottom to surface that aimed at specific groups of organisms. Trawl net being not a very selective gear, grabs most of the fishes found in its towing path. In general non-commercial species in the by-catch are being discarded back into the sea, a practice called discarding[4]. Whereas the fish protein of any form became an important raw material for feed and fertiliser production, most of the low value bycatch (LVB) brought to the shore are kept without much preservation and utilised widely to feed livestock/fish, either directly or as fish meal/oil[5]. Intensity of trawling has a dreadful impact on benthic ecology and biodiversity[6].

Unintended catch of non-target creatures has become a severe problem faced by trawl fisheries all over the world[7]. LVB landings not only contain non-profitable fishes, but also juveniles of several commercially important fishes of below minimum landing size (MLS) / less profitable owing to market conditions[8,9]. The biological and economic loss due to large number of juveniles in LVB is one of the important issues that has to be tackled by the fishery managers[10]. The international bodies like FAO has taken the resource damage due to bottom trawling critically and urged to reduce or eliminate bycatch, fish discards, post-harvest losses and to support studies/research to either reduce or eliminate bycatch of juvenile fish[11]. The first trawling attempt in Indian waters was by the mechanized vessel *S.T. Premier* in 1900 off Bombay coast[12,13] and by the Ceylon Company for Pearl Fishing Survey[14]. In Karnataka state, bottom trawling was first introduced in 1961 by the Japanese trawler *M.S. Kaiko Maru*[15]. High valued resources *viz.,* prawns, squids, cuttlefish, threadfin breams and ribbonfish are the target species of trawlers in Karnataka[16]. Karnataka has a 300 km coast endowed with 27,000 km$^2$ continental shelf. Trawlers (78 %) are the major contributor to the fish production from mechanised sector. There are about 96 fish landing centres in the state. Mangaluru in Dakshina Kannada district, Malpe in Udupi and Karwar in Uttara Kannada districts are main landing centres. Mangaluru fisheries harbour is one of the important marine fisheries harbours, contributing more than 40 percent of the total catch of Karnataka[17].

In shrimp targeted 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 corals, weeds and seabed debris. Occasionally this is called accidental or incidental catch. Alverson *et al.*[18] opined that mainly there are three accepted definitions of bycatch. In some places, bycatch is the catch, which is retained and sold, that is not target species. In some other places, bycatch means fishes of non-preferred sizes and sexes which are discarded. Bycatch and discards are the common problems handled by all fishing activities globally and it is a main 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 believed as unavoidable in any kind of fishing but the quantity varies according to the gear operated[19-21]. 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[22]. The extent of resource damage due to bycatch landings by trawlers is increasing in alarming status from the fishery resource conservation and sustainability point of view[23]. The term LVB in the present study indicates the fish catch landed without much preservation for non-edible purpose (trash). The present study aimed at quantification of LVB (trash), species composition and the magnitude of resource damage implied due to landing of commercially important finfish juveniles in trash fish from trawlers operating, off Mangaluru, Karnataka.

## Materials and methods

Fish landing data on commercial (edible) catch and LVB were collected from trawl boats operated from Mangaluru fisheries harbour during the fishing seasons of 2012-14 years. The fish catch data *viz.* total quantity of fish landed, low value bycatch (trash fish) contribution and other fishing information was collected from 10 % of the total number of trawl boats for 16 days in a month by adopting the stratified random sampling design developed by CMFRI. Catch and species composition of trash fish were estimated on monthly basis[24]. Along with the fishing information, an unsorted portion of LVB (trash) samples preserved in ice were collected thrice in a month and taken to the laboratory to identify the fishes up to species level[25-27]. Quantitative and qualitative analysis of the samples were carried out in the laboratory. Species present in the sample were sorted out, identified and also the number, length and weight of individual fishes of each group were recorded.

Commercial species of finfish species 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[28]. Total number of juveniles of individual species was noted down and average weight of individual species was recorded. Commercially important finfish species proportion in number and weight recorded from LVB (trash) landings was calculated. 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 by following the formulas[16].

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

$$\text{Projected juvenile weight of individual species} = \text{Projected juvenile number of individual species} \times \text{Average weight of individual species}$$

The following terms and definitions[29] are adopted in this study: 'total catch' is the total quantity of all species brought onboard. 'Landed catch' is part of the total catch that has economic value (*i.e.* the quantity of fish for edible purpose and low valued species as non-edible usage). 'Total bycatch' is the portion of the total catch, which may be retained if it has commercial value (LVB) or discarded at sea if it is not used for any purpose (discarded bycatch). The term "LVB (trash) used in this article represents the non-edible part of landed bycatch only.

## Results

*Quantification of LVB landings by trawlers at Mangaluru*

The trawl catch estimated at Mangaluru during the fishing season of 2012-13 was 1.73 lakh t out of which 140 thousand t (81 %) retained for commercial purpose and 32 thousand t (19 %) was LVB (trash). In 2013-14 the total fish landings by trawlers was reduced to 162 thousand t of which only 125 thousand t (77 %) were landed as edible fish and the LVB increased to 36 thousand t (23 %) (Fig. 1). Monthly variation of trash landings showed that maximum LVB landing was recorded in May 2013 (5,345.8 t) followed by Apr. 2014 (5,297.2 t), May 2014 (4,930.4 t) and other months. Whereas the lowest landing of LVB was recorded in August 2013 (169.4 t) followed by August 2012 (218.3 t) and December 2012 (2,532.2 t) (Fig. 2). It is clear from Fig. 2 that the trash landings were more throughout Pre monsoon months followed by Post monsoon months. During monsoon months LVB landings were comparatively less as demand for trash was comparatively low because of erratic weather conditions and availability of huge catch of commercially important fishes immediately after monsoon ban.

The percentage contribution of commercial catch and LVB landings revealed that as the percentage of commercial landings reduced, landings of LVB increased substantially and vice versa. Highest contribution of LVB to the total landings was recorded in November 2013 with 28.8 %, which declined to 28.7 % in April 2014 and 28.3 % in March 2014. On the other hand the lowest per cent contribution was recorded in August 2012 (10.7 %) followed by October 2013 (12.8 %) and September 2012 (12.9 %) (Fig. 3). Stomatopods were the dominant group of trash landed by single day trawlers (SDT) with an average contribution of 61 % during the study period. Other than stomatopods, 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 and their percentage composition of LVB (trash) landed by MDT during

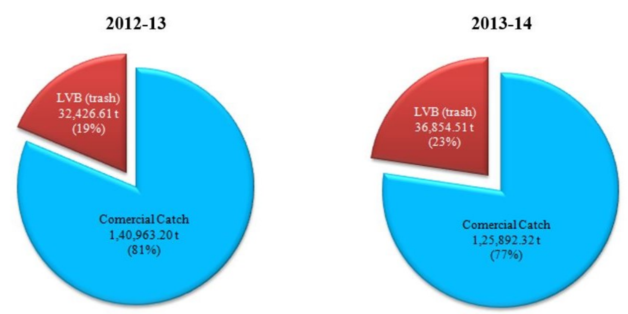


Fig. 1 — Landings of commercial fishes and low value bycatch (trash) by trawlers of Mangaluru

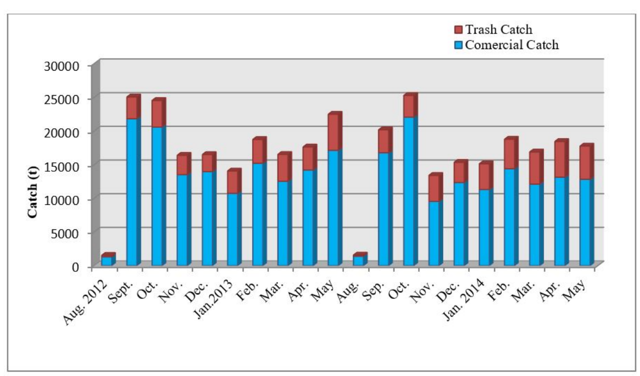


Fig. 2 — Monthly variation in the contribution of commercial catch and low value bycatch landings by trawlers during 2012-14

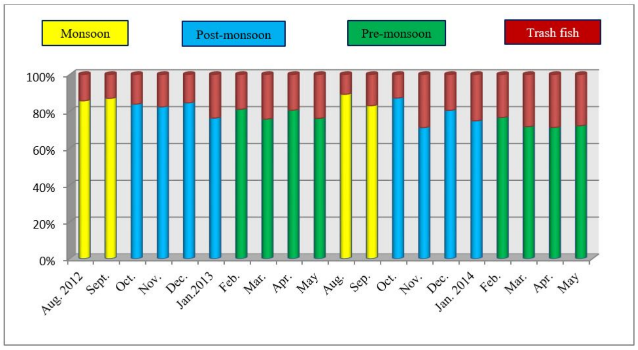


Fig. 3 — Monthly variation in the % contribution of commercial catch and low value bycatch landings by trawlers during 2012-14

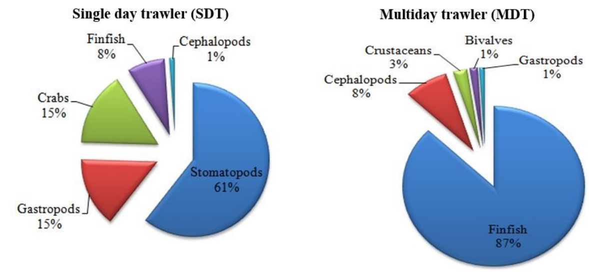


Fig. 4 — Major group of species and their % composition of LVB (trash) during 2012-14

study period revealed that finfish were the dominant group (87 %) landed as LVB. Cephalopods were next to finfish which contributed on an average of 8 % and groups, Crustaceans (3 %), Bivalves and Gastropods (1 % each) contribution was meagre to the trash landings (Fig. 4).

*Profile of trawl LVB finfish composition*

Analysis of LVB samples from multiday trawlers showed 121 finfish species belonged to 82 genera, 55 families and 13 orders landed at Mangaluru fisheries harbour. The LVB consists of juveniles of many commercial species and rest were adult and juveniles of species with no market value. Details of the species catch composition, and percentage contribution showed that the species *Lagocephalus inermis* contributed 6,788.4 t to the total finfish LVB landings with 23 % of weight followed by *Decapterus russelli* with 5,347.2 t (18 %), *Trichiurus lepturus* with 1,978.7 t (7 %), *Rastrelliger kanagurta* with 1,931.3 t (nearly 7 %), *Dussumieria acuta* with 1,734.3 t (6 %), *Saurida tumbil* with 1,429.5 t (5 %), *Mene maculate* with 1,099.1 t (4 %), *Muraenesox* sp. with 715.3 t, *Platycephalus indicus* with 712.1 t, *Encrasicholina devisi* with 697.1 t *Sardinella longiceps* with 657 t, *Uranoscopus* spp. with 645 t (approximately 2 % each) and all other species together formed 20 % of the total finfish LVB landings (Fig. 5).

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

Results of percentage number contribution by finfishes revealed that *Decapterus russelli* was the most dominant species which contributed 16.2 % to the total number of fish landed followed by *Lagocephalus inermis* (14.3 %), *Rastrelliger kanagurta* (8.4 %), *Saurida tumbil* (7.6 %), *Photopectoralis bindus* (7 %) *Encrasicholina devisi* (6.5 %), *Platycephalus indicus* (4.8 %), *Nemipterus randalli* (4.6 %), *Trichiurus lepturus* (4 %), *Sardinella longiceps* (3 %) *Dussumieria acuta* (2.3 %), *Leiognathus* sp. (2.2 %), *Mene maculate* (1.5 %), *Fistularia petimba* (1.3 %), *Terapon* spp. (1.3 %), *Epinephelus diacanthus* (1.2 %) *Apogon* sp. (1.2 %), *Muraenesox* sp. (1.1 %), *Sardinella* spp. (1 %), whereas all other species contributed approximately 10 % to the total number of finfish species landed (Fig. 5).

*Percentage of juveniles of commercially important finfishes in trash fish*

From the present study it was observed that finfishes landed as LVB were both non-commercial and commercial species. Smaller size was the criteria for commercial species. To find out the percentage composition of commercially important finfish juveniles in trash landings, minimum size at maturity was used for juvenile segregation. During the study it was noticed that on an average 47.5 % of the finfish LVB landings were juveniles of commercially important species and in terms of number they contributed 56.1 %. From the fisheries sustainability point of view, resource loss in respect of number is more significant than the weight, since maximum portion of the LVB were juveniles which forge the back bone of the fishery for future. Juveniles of *Decapterus russelli* placed in a top position by contributing on an average 13.9 % to the number and 15.9 % to the weight followed by *Saurida tumbil* (7.4 % and 4.7 %), *Rastrelliger kanagurta* (7.3 % and 5.7 %), *Photopectoralis bindus* (6.3 % and 1.1 %), *Platycephalus indicus* (4.8 % and 2.5 %), *Nemipterus randalli* (4.6 % and 1.2 %), *Trichiurus lepturus* (2.5 % and 4.8 %), *Sardinella longiceps* (2.4 % and 1.8 %), *Epinephelus diacanthus* (1.2% and 1.3%), *Mene maculata* (1% and 2.6%), *Muraenesox* spp. (1 % and 2 %) and all other juveniles of commercially important species formed 3.9 % to the number and

4.1 % to the weight of finfish LVB landings of the study period (Table 1).

*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 most of the commercially important species extent from shrimps, cephalopods, demersal fishes and also juveniles of pelagic fishes. The estimated LVB quantity for Mangaluru Fisheries

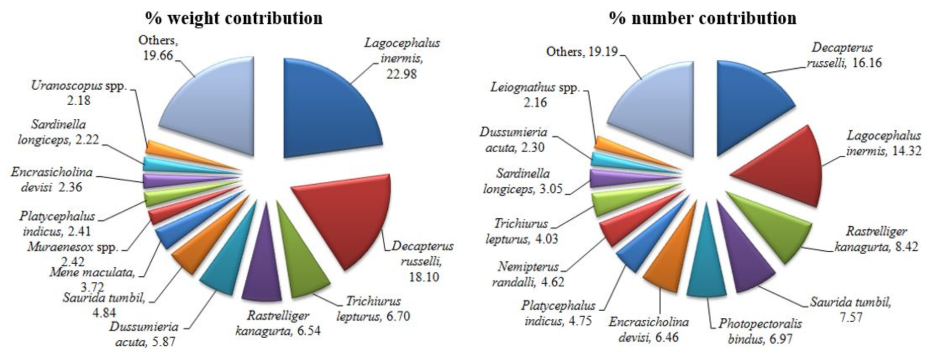


Fig. 5 — Diagrammatic representation of the % weight and % number contribution of major species during 2012-14

Table 1 — The percentage of juveniles of commercially important finfish species in number and weight recorded from LVB (Trash) landings by trawlers of Mangaluru during 2012-14

| Species name | % by Number | | | % by Weight | | |
|---|---|---|---|---|---|---|
| | 2012-13 | 2013-14 | 2012-14 | 2012-13 | 2013-14 | 2012-14 |
| *Decapterus russelli* | 11.233 | 16.292 | 13.902 | 14.216 | 16.862 | 15.885 |
| *Saurida tumbil* | 6.500 | 8.191 | 7.392 | 4.322 | 5.063 | 4.724 |
| *Rastrelliger kanagurta* | 7.770 | 6.863 | 7.292 | 6.247 | 5.170 | 5.657 |
| *Photopectoralis bindus* | 6.998 | 5.698 | 6.312 | 1.506 | 0.848 | 1.138 |
| *Platycephalus indicus* | 5.870 | 3.750 | 4.752 | 2.574 | 2.275 | 2.494 |
| *Nemipterus randalli* | 5.728 | 3.586 | 4.599 | 1.550 | 0.826 | 1.145 |
| *Trichiurus lepturus* | 3.088 | 1.930 | 2.477 | 4.099 | 4.830 | 4.795 |
| *Sardinella longiceps* | 0.538 | 3.968 | 2.347 | 0.429 | 2.771 | 1.746 |
| *Epinephelus diacanthus* | 1.127 | 1.329 | 1.234 | 1.504 | 0.991 | 1.264 |
| *Mene maculata* | 1.544 | 0.491 | 0.989 | 3.591 | 1.397 | 2.561 |
| *Muraenesox* spp. | 0.934 | 0.956 | 0.946 | 2.185 | 1.958 | 2.064 |
| *Encrasicholina devisi* | 0.843 | 0.300 | 0.557 | 0.295 | 0.125 | 0.213 |
| *Saurida undosquamis* | 0.244 | 0.674 | 0.470 | 0.078 | 0.341 | 0.196 |
| *Dussumieria acuta* | 0.518 | 0.228 | 0.365 | 1.461 | 0.517 | 0.923 |
| *Sardinella* spp. | 0.000 | 0.674 | 0.355 | 0.000 | 1.055 | 0.522 |
| *Megalaspis cordyla* | 0.538 | 0.182 | 0.350 | 0.520 | 0.076 | 0.238 |
| *Psettodes erumei* | 0.183 | 0.391 | 0.293 | 0.116 | 0.245 | 0.184 |
| *Lactarius lactarius* | 0.508 | 0.000 | 0.240 | 0.226 | 0.000 | 0.149 |
| *Trachinocephalus myops* | 0.163 | 0.273 | 0.221 | 0.250 | 0.515 | 0.379 |
| *Nemipterus japonicus* | 0.081 | 0.300 | 0.197 | 0.037 | 0.138 | 0.090 |
| *Priacanthus hamrur* | 0.183 | 0.137 | 0.158 | 0.517 | 0.154 | 0.307 |
| *Sphyraena* spp. | 0.305 | 0.009 | 0.149 | 0.214 | 0.017 | 0.198 |
| *Secutor insidiator* | 0.223 | 0.000 | 0.106 | 0.030 | 0.000 | 0.019 |
| *Cynoglossus bilineatus* | 0.091 | 0.109 | 0.101 | 0.010 | 0.021 | 0.016 |
| *Stolephorus waitei* | 0.173 | 0.000 | 0.082 | 0.045 | 0.000 | 0.029 |
| *Alectis indica* | 0.030 | 0.091 | 0.062 | 0.132 | 0.212 | 0.205 |
| *Scomberomorus commerson* | 0.112 | 0.000 | 0.053 | 0.160 | 0.000 | 0.036 |
| *Gymnothorax annulatus* | 0.030 | 0.036 | 0.034 | 0.135 | 0.251 | 0.191 |
| *Lutjanus* spp. | 0.020 | 0.036 | 0.029 | 0.047 | 0.200 | 0.114 |
| *Cynoglossus macrostomus* | 0.041 | 0.009 | 0.024 | 0.019 | 0.002 | 0.008 |
| *Rachycentron canadum* | 0.010 | 0.009 | 0.010 | 0.010 | 0.057 | 0.036 |
| *Johnius* spp. | 0.010 | 0.000 | 0.005 | 0.032 | 0.000 | 0.007 |
| | **55.637** | **56.512** | **56.101** | **46.557** | **46.919** | **47.534** |

Harbour during the study period was on an average 29,547 t/yr. 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.

In 2012-14, 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/yr respectively. Similarly other species such as *Rastrelliger kanagurta* (142.9 million and 1,671.4 t) *Photopectoralis bindus* (123.7 million and 336.2 t), *Platycephalus indicus* (93.1 million and 737 t), *Nemipterus randalli* (90.1 million and 338.3 t), *Trichiurus lepturus* (48.5 million and 1,416.6 t), *Sardinella longiceps* (46 million and 515.9 t), *Epinephelus diacanthus* (24.2 million and 373.5 t), *Mene maculata* (19.4 million and 756.5 t), *Muraenesox* spp. (18.5 million and 609.8 t), *Encrasicholina devisi* (10.9 million and 63.1 t) and other juveniles of commercially important species (64.7 million number and 1,136.6 t) contributed in number and weight/yr respectively to the LVB landings (Table 2).

Table 2 — Estimated resource damage to commercially important fisheries resources off Mangaluru during 2012-14

| Species name | Juvenile Length (cm) | Avg. wt (g) | Avg. 2012-14 Juveniles no (million) | Avg. 2012-14 Juveniles wt (t) |
|---|---|---|---|---|
| *Decapterus russelli* | 14 | 17.23 | 272.44 | 4693.39 |
| *Saurida tumbil* | 25 | 9.63 | 144.87 | 1395.68 |
| *Rastrelliger kanagurta* | 16 | 11.70 | 142.90 | 1671.43 |
| *Photopectoralis bindus* | 7.4 | 2.72 | 123.71 | 336.19 |
| *Platycephalus indicus* | 40 | 7.91 | 93.13 | 736.97 |
| *Nemipterus randalli* | 12.8 | 3.75 | 90.12 | 338.34 |
| *Trichiurus lepturus* | 48 | 29.18 | 48.54 | 1416.64 |
| *Sardinella longiceps* | 12 | 11.21 | 46.00 | 515.91 |
| *Epinephelus diacanthus* | 18 | 15.45 | 24.18 | 373.52 |
| *Mene maculata* | 14 | 39.04 | 19.38 | 756.53 |
| *Muraenesox* spp. | 120 | 32.90 | 18.53 | 609.79 |
| *Encrasicholina devisi* | 6 | 5.78 | 10.91 | 63.07 |
| *Saurida undosquamis* | 17 | 6.27 | 9.22 | 57.82 |
| *Dussumieria acuta* | 12.5 | 38.13 | 7.15 | 272.62 |
| *Sardinella* spp. | 12 | 22.16 | 6.96 | 154.29 |
| *Megalaspis cordyla* | 22 | 10.24 | 6.87 | 70.29 |
| *Psettodes erumei* | 37 | 9.46 | 5.74 | 54.30 |
| *Lactarius lactarius* | 12.5 | 9.37 | 4.70 | 44.09 |
| *Trachinocephalus myops* | 15 | 25.86 | 4.33 | 111.89 |
| *Nemipterus japonicus* | 13.8 | 6.92 | 3.86 | 26.68 |
| *Priacanthus hamrur* | 19 | 29.19 | 3.10 | 90.63 |
| *Sphyraena* spp. | 40 | 20.05 | 2.92 | 58.47 |
| *Secutor insidiator* | 7.8 | 2.71 | 2.07 | 5.61 |
| *Cynoglossus bilineatus* | 10 | 2.32 | 1.98 | 4.59 |
| *Stolephorus waitei* | 7 | 5.44 | 1.60 | 8.69 |
| *Alectis indica* | 17 | 49.42 | 1.22 | 60.44 |
| *Scomberomorus commerson* | 70 | 10.32 | 1.03 | 10.68 |
| *Gymnothorax annulatus* | 30 | 85.89 | 0.66 | 56.56 |
| *Lutjanus* spp. | 29 | 59.88 | 0.56 | 33.80 |
| *Cynoglossus macrostomus* | 7.5 | 5.20 | 0.47 | 2.45 |
| *Rachycentron canadum* | 43 | 56.25 | 0.19 | 10.58 |
| *Johnius* spp. | 14 | 22.50 | 0.09 | 2.12 |

## Discussion

In tropical countries like India, the bycatch problem is more complex due to the multi-species nature of the fisheries. In the present study the LVB landings formed on an average 21.5 % (35 thousand t) of the trawl catch. The average LVB to target group ratio during 2012-14 was 1 : 3.9. Monthly variation of trash landings showed that maximum LVB landing was recorded in May 2013 (28.8 %) followed by Apr. 2014 (28.7 %). It was observed by Rao[30] that the quantity of bycatch discarded in Visakhapatnam (India) depended on the demand for finfishes in the outward and domestic market. Jayaraman[31] estimated LVB to constitute 10-20 % of total catches landed by trawlers operating along the Indian coast in 2003. Dineshbabu *et al.*[32] observed that there was a phenomenal increase in landings of LVB landings at Mangaluru fisheries harbour as well as in other major landing centres of the country. The trash fish landing at Mangaluru rose from only 3 % in 2008 to 26 % of trawl catch landed in 2011. This increase in trash landings was due to augmented demand from the fish meal plants operating all along the Karnataka coast. Decline in oil sardine landings resulted in a crisis of raw material to respond to the demand for fishmeal. Trash fish provided a viable alternative for fish meal production. Menon *et al.*[33] reported that the ratio of target : bycatch throughout the south-west and south-east regions of India were 1 : 4.6 and 1 : 1.3, respectively. The demand for targeted fish resources has tiled way for indiscriminate bottom trawling along the coast with an ultimate result of massive wastage of low value, high volume bycatch including an extensive range of non-edible benthic biota[34].

Results are evident that, LVB landings were high during pre-monsoon months, when conditions were propitious for fish drying and the demand for LVB (trash) was maximum followed by post monsoon months than monsoon months. In Mangaluru it was perceived that maximum landing of LVB was during pre-monsoon months of 2008-2009 and during rainy and post-monsoon seasons, the discard proportion was more than those landed as trash (LVB)[16]. Throughout the west-coast of India, almost all bycatch landed were utilized for fishmeal and fertiliser production[23,35,36].

During the present study period stomatopods found to be dominant group of trash landed by SDT and finfishes from MDT. Menon[37] found that the quantity of LVB landed by bottom trawlers in Karnataka, Kerala and Tamil Nadu states was dominated by finfishes in MDT and stomatopods in SDT during 1985-90. Squilla, though doesn't have economic impact, has significant ecological importance as it forms one of the food item of a large number of demersal organisms[38]. Studies on bycatch and discards associated with bottom trawling along Karnataka coast also revealed that the most prominent group among bycatch was stomatopods in SDT and finfishes in MDT[16,34]. Thus, the results of the present study are comparable with the earlier studies.

From the results of present study it is clear that the price for the LVB was decided by the composition of the LVB. Finfish prepotent LVB fetched as high as ₹ 16/kg during summer months, which was mostly landed by multiday trawlers in a semi-preserved form. LVB landed by single day trawlers mainly consisted of stomatopods and gastropods (crustaceans and molluscs) fetched only ₹ 6/kg due to less finfish composition. Study on changing trends in bycatch utilisation in peninsular India revealed that finfish dominant LVB fetched as high as Rs. 12/kg, which was mainly utilised for fish meal preparation. Molluscs and crustaceans dominated LVB landed by single day trawlers fetched merely Rs. 4/kg, which was mainly utilised for low cost fishmeal after drying[32].

From the sustainability point of view it is important to assess the species composition and the juvenile composition of LVB landings. A total 121 finfish species were recorded in LVB landed by MDT from August 2012 to May 2014. Growth over fishing was observed in present study and there were number of commercial fishes being sold as LVB due to smaller size which is not preferred in markets. Carangidae family contributed 11.6 % (14 species) to the 121 species followed by Engraulidae and Leiognathidae (6.6 % each) were the major families. The order Perciformes contributed 61.2 % (74 species) followed by Clupeiformes (10.7 %) and other orders. Sujatha[39] studied finfish constituents of trawl bycatch off Vishakapatanam and reported 228 species belonged to 68 families as a constituent of finfish bycatch of small trawlers landed at Visakhapatanam. The bycatch constituted small-sized, non-edible species and juveniles of commercially important species. According to the observations of Pravin and Manohardoss[40] 87 species belonging to 42 families constituted 82.7 % of the LVB landed by mechanised trawlers operated off Veraval. Sciaenids were the major group contributed 15.6 % followed by engraulids (12.84 %), ribbon fishes (8.9 %), penaeid and non penaeid prawns (8.2 %). Dineshbabu *et al.*[16] recorded a total of 116 species of finfishes from discard portion of MDT during 2008-2009. Lizard fishes, puffer fishes, threadfin breams and flatheads were the chief contributors.

During the 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 (16.2 %) by number to the total number of finfish landed as LVB followed by *Lagocephalus inermis* (14.3 %). Dineshbabu *et al.*[16] reported that *Saurida* spp. contributed maximum to the LVB by weight (12.7 %) 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 LVB in Mangaluru fisheries harbour.

Mangaluru fisheries harbour 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. During 2012-14, it was observed that on an average 47.5 % of the finfish LVB landings were constituted by juveniles of commercially important species and in terms of number they formed 56.1 %. In Mangaluru fisheries harbour it was estimated 63.7 % (by numbers) of LVB was constituted by commercially important fish juveniles during the year 2007-2008, causing substantial damage to the stocks of these species. With regard to weight, commercially important species formed 37.4 % of total bycatch[41]. According to the recent studies by Dineshbabu *et al.*[32] juveniles of 14 commercial species were recorded every month from discards of trawlers of Mangaluru during 2008-2011. The contribution of commercially important species juveniles in discard by number was assessed as 63.7 % and in terms of weight they formed 37.4 %.

The quantity of commercially important finfish juveniles was estimated to be 14,044 t in LVB at Mangaluru Fisheries Harbour during 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. Jayaraman[31] estimated 1,549 t of the young / juvenile fish bycatch in SDT and 9,077 t in MDT from the Mangaluru - Malpe trawl landing base. In 2012-14, juveniles of *Decapterus russelli* was the dominant commercial resource that landed as LVB which was estimated to be on an average 272.4 million number of landed as trash/yr and the weight estimated was 4,693.4 t. *Rastrelliger kanagurta* which is one of the dominant pelagic fish resource of the south-west coast, landed 142.9 million number/yr 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 Mangaluru landed 90.1 million in number and weight estimated was 338.3 t. During 2008-2009 juveniles of *Platycephalus* sp. landed about 2,733 t in discards of trawlers of Mangaluru. The discarded number estimated was 464 million. *Nemipterus randalli,* one among the highest contributors to trawl fish landings at Mangaluru also contributed considerably in the discards and the quantity thrown out was 1,341 t and 333 million in numbers. Juveniles of valuable resources like, seerfishes, cephalopods, cobia, shrimps, groupers and snappers were also found in substantial mass and numbers from the discards.

The study depicted that juvenile fish landing as LVB could affect the fish stock and consequently the fishery economy by subsequent reduction in commercial fish landings in succeeding years. Preliminary experiments on spatio-temporal resource mapping using Geographic Information System (GIS) based studies have helped in identification of critical fishing grounds which would consider as “no fishing zones” and “marine sanctuaries” to reduce the resource damage by effort reduction in such grounds[16].

The significance of Bycatch Reduction Devises 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[42-45]. Since juveniles contribute 40 % to the bycatch in India a Juvenile Fish Excluder-Shrimp Sorting Device (JFE-SSD) has been developed for bringing down the juveniles as bycatch and small sized non-targeted fishes in commercial shrimp trawl[46]. The JFE-SSD operations off Cochin, India had realised LVB reduction up to 43 % with 96-97 % shrimp retention[47]. Ganga *et al.*[48] opined that the Code of Conduct for Responsible Fisheries (CCRF) specify that while the aim of maximizing returns are strived by the fishermen, it should be done without deleteriously affecting the self-sustaining nature of the fishery resources and with least ramification on the ecosystem. The Central Marine Fisheries Research Institute (CMFRI) and Central Institute of Fisheries Technology (CIFT) have recommended the following eco-friendly approaches to ensure indelible sustainability of the fishery sector:

- Employ square meshed trawl nets with 35 mm codend which curtails juvenile fish catch.
- Desist from use of high Horse Power (HP) (> 250 HP) engines and restrict the upper limit of 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).
- Employ JFE-SSD in trawls which have an *in-situ* sorting effect (LVB reduction up to 43 %, and shrimp holding of 95 % with capability to eliminate jellyfish).
- Use only > 22 mm meshed seine nets while intending to catch pelagic fishes like mackerel and oil sardine.
- Willingly avoid juvenile fish shoals during fishing activity using seine nets.

## Conclusion

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. Bycatch intrinsic in trawl fishery is a main constituent along the coast of India, as in any tropical country. Juveniles landing in LVB from the Indian fisheries has a significant impression on marine trophic structure. Trade and industry attentions play a key role in the quantity of LVB landed and discarded. Trawlers equipped with advanced technologies in fishing and high storage capacity are diligently trawling to fish as much as possible with no concern over the size or the species of fish or the future concerns about the fishery. This practice resulted in substantial exploitation of commercially important fish juveniles and ecologically important biota. Bycatch landing in trawl fisheries is unavoidable in multi-species scenario due to existence of trawling as backbone of Indian marine fisheries. Bycatch problem to a greater level can be sensibly addressed by allowing trawling with bigger codend meshed nets, trawl ban in certain seasons, adoption of JFE-SSD and effort reduction in critical fishing grounds can bring down the damages to the ecosystems by reducing juveniles in bycatch considerably.

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