*Fishery Technology* 52 (2015) : 228 - 236

# Influence of Codend Mesh Size on Bycatch Composition of Two Trawls Operated off Veraval, Gujarat, India

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## Abstract

The deleterious impact of bottom trawling on benthic ecosystem is widely reported and attempts are made to reduce bycatch generated by trawling through technical and operational measures. Systematic baseline data on the quantity and type of bycatch will help in comparing the changes that have occurred to the fish community structure. This study compares the bycatch generated by two trawling systems with 15, 20, 30 and 40 mm mesh size codends off Veraval during 1991-92 and 2005-06. Analysis of quantity of bycatch generated and changes in species composition, analysis of diversity and multivariate analysis were carried out to elucidate the changes on the community structure along the Veraval coast. The percentage of total bycatch generated in trawl systems during 1991-92 were 25.69±4.28 and 31.03±1.58 with 15 and 30 mm codend meshes respectively while the values were 67.77±3.22 and 22.15±2.44 respectively for 20 and 40mm codends during 2005-06. *Acetes* spp and *Otolithes ruber* contributed the major share of bycatch in the 15 and 30 mm codends, whereas *Trichiurus lepturus* and *Rhopilema* spp were the major species caught during 2005-06 in the 20 and 40 mm codend mesh respectively. Highest diversity was observed in the 15 mm codend as indicated by both the indices of diversity 'S and d'. ANOSIM test revealed that the difference in the assemblage structure during the years were significant with a global 'R' value of 0.176. The results of the SIMPER analysis showed that the average dissimilarity between the bycatch assemblages during the years 1991-92 and 2005-06 was noticed to be 87.23%. It was evident from the studies that there are changes in the quantity and assemblage structure of the bycatch generated by different trawling systems over the years. This study also shows the utility of increasing the mesh sizes as a technical measure to reduce impacts of trawling on biodiversity.

**Keywords:** Trawling, bycatch, codend, SIMPER, ANOSIM, diversity

## Introduction

Trawling is the major fishing method along the northwest coast of India, contributing to about 56% of the total catches (CMFRI, 2011). Bottom trawling along the Gujarat coast contribute about 61% of the total landings of the state (CMFRI, 2012). Trawling was introduced in Gujarat in 1964 with the commissioning of a 10.97 m $L_{OA}$ wooden stern trawler at Veraval (Deshpande & Kartha, 1964) and this has paved way for the development of trawling as a major fishing tecnique in this region (George Mathai et al., 2003; Mohanrajan et al., 1989). Two types of trawlers are commonly found along the Gujarat coast. The small and medium size fishing vessels, within the size class of 30-45 ft, undertake single day operations along the coastal waters. The second category with lengths ranging from 45-55 feet, undertake voyage fishing of 8-10 days duration along 60-100 m depth. The fishing operations usually start from September after the ban period (Gujarat Government Gazette, 2003) and continue up to May. Since this area is a good ground for the bottom and off-bottom fishes and cephalopods, majority of the trawl nets are designed to target these resources (George Mathai et al., 2003; Kunjipalu et al., 1979a; Kunjipalu et al., 1979b; Pravin & Vijayan, 2002).

Large quantities of bycatch generated during fishing may lead to loss of marine biodiversity, which will

Received 12 August 2015; Revised 05 September 2015; Accepted 26 October 2015

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impair the structure and function of the marine ecosystems (Stokstad, 2006; Worm et al., 2006). Changes in fish community structure and diversity pattern have been related to fishing pressure prevailing in the ecosystem (Jennings & Kaiser, 1998). There are many studies that reveal the negative impacts of trawling on the marine ecosystem (Goni, 1998; Hall & John, 2001; Planque et al., 2010). Similarly, enough evidence has been gathered on the deleterious impact of trawling on non-target communities in different ecosystems (Stobutzki et al., 2001; Stobutzki et al., 2006). Attempts are made world over to reduce the quantity of bycatch generated in trawling by use of bycatch reduction devices (BRDs) and improved designs of trawl nets (Brewer et al., 1996; Brewer et al., 1998; Broadhurst et al., 2002; Halliday & Cooper, 1999) and other technical measures. Some of the studies on the bycatch and discards by trawling along the West coast of India are by George et al. (1981), Kurup et al. (2003; 2004), Pravin & Manohardoss (1996).

Characterization and quantification of the bycatch generated by a fishery in an area helps to substantiate the intensity of the impact and aid in implementing management measures for regulating the fishery. Systematic data on the quantity and biodiversity level impacts on the ecosystem is inadequate in the Indian context (Kumar & Deepthi, 2006; Zeller & Pauly, 2005).

Species diversity in the bottom trawls is reported to be three times that of the targeted catches (Nair et al., 2003). The quantity and diversity of bycatch generated by bottom trawling in the tropical waters is much higher (Hall, 1996) and the impact of fishing on biodiversity can be more insightful if the bycatch (incidental catches) is studied. Species characterization studies during different periods and their comparison will indicate the impacts on species diversity over the years (Jin & Tang, 1996; Xu & Jin, 2005).

The aim of the study was to determine the changes in assemblage structure of the incidental catches due to the use of different mesh sizes in the codend using relative biomass of species (or species groups) and the species assemblages approach.

## Material and Methods

Data on the bycatch generated by trawls with four codend mesh sizes *viz.*, 15 and 30 mm during 1991-92 and 20 and 40 mm during 2005-06 off Veraval coast were used in this study. The data collected by experimental trawling operations using two Departmental fishing vessels (MFV Fish Tech- VIII, wooden trawler of LOA15.5 m, 185 hp, and MFV Sagarkripa, LOA 15.5 m steel trawler with 125 hp) of ICAR-CIFT during 1991-92 and 2005-06 respectively, off Veraval coast was used for the study. High opening bottom trawl (HOBT) with 36 m head rope (HR) length with two codend having 15 and 30 mm mesh sizes were used alternately during the 1991-92 and 61 hauls were made. 112 hauls were made using 34 m HOBT with codend mesh size of 20 and 40 mm alternately during 2005-06.

The towing speed varied from 2 to 2.5 knots during both the periods. Since tow durations were different and it was normalized and CPUE was expressed as weight in kilograms per hour (kg $h^{-1}$). Since the trawl nets used during the different periods were different in dimensions, the total spread area of the two nets was calculated (Prado, 1990). Weight of all the species caught in the 36 m trawl were scaled down by multiplying with a factor (s=0.954). The trawl catches were segregated onboard to targets and incidental, based on the consumer preference and the incidental catches in each haul were further segregated and identified up to the species level. The length and weight of the individual fish were noted and whenever the quantity was large, a sub-sample, weighing about 20% of the total weight of the group were randomly taken for the measurements and scaled-up for calculations.

Analysis was carried out to assess the changes in the quantity of bycatch generated and the contribution of commercial species in the bycatch. Diversity was analytically decomposed in its components using estimates of richness, evenness, and heterogeneous indices to assess the changes in the assemblage structure. Two indices *viz.,* total number of species (S), in each haul and the Margalef index (d), since this index adjusts the number of species according to the total number of individuals obtained in each haul (Magurran, 2004). Smith and Wilson Index (Evar) and Shannon-Wiener (H'loge), which are heterogeneous indices that combine the diversity and evenness components were also derived. Hill N1 and Hill N2 (Hill, 1973) indices were used since they were sensitive to changes in the rare and dominant species respectively (Greenstreet et al., 1999). Since the hauls (samples) used for comparisons between the different codend mesh sizes were not same, bootstrapping was carried out (Franco-

Gordo et al., 2008). The number of hauls for each mesh size was fixed as 200, to calculate the mean and the 95% confidence intervals of the estimated indices of diversity (the rarefaction curves for the different trawling systems indicated that the cumulative curve reached an asymptote with around 100 hauls).

Multivariate analysis was carried out to reveal changes in the assemblage structure between the years and between the different mesh sizes. Analysis of similarity (ANOSIM) was used to test the overall differences in the incidental catches from the different trawling systems (Clarke, 1993). ANOSIM was carried out on the fourth- root transformed and standardized data of the species assemblage matrix with 999 permutations using Bray-Curtis as the similarity measure. Similarities percentage analysis (SIMPER) was carried out (Clarke & Warwick, 1994) to identify the fish species that contribute to between and within differences between the gear systems studied and a non-metric multi-dimensional scaling (MDS) was used to generate a two-dimensional ordination of the assemblages in Bray-Curtis space (Bray & Curtis, 1957).

## Results and Discussion

The mean percentage of incidental catches generated by different trawling systems during different periods and significant differences between them (p=0.05) are shown in Fig. 1 and Table 1. The average weight of bycatch generated by the systems for producing a unit weight of target catch is also depicted in the figure. The percentage of total bycatch generated by trawl systems with 30, 15, 20 and 40 mm codend meshes were 31.03±1.58, 25.69±4.28, 67.77±3.22 and 22.15±2.44 respectively. Weight of bycatch (kg) generated per unit value of target catch in the different systems were 0.46±0.03, 0.91± 0.13, 4.12±0.58 and 0.67±0.14 respectively for the 30, 15, 20 and 40 mm codend mesh sizes. The proportion of incidental catches generated by the 20 mm codend mesh was significantly different from the other trawling systems (p<0.05).

Highest quantity of incidental catches was noticed for 20 mm mesh size during 2005-06 and was followed by 15 mm mesh size codend during 1991-92. The lowest average bycatch was recorded for 30 mm mesh size codend operated during 1991-92. The high proportion of bycatch in 20 mm mesh 4.12±0.58 can be due to the lower selectivity of the codend and the proportion is reduced drastically to (0.67±0.14)

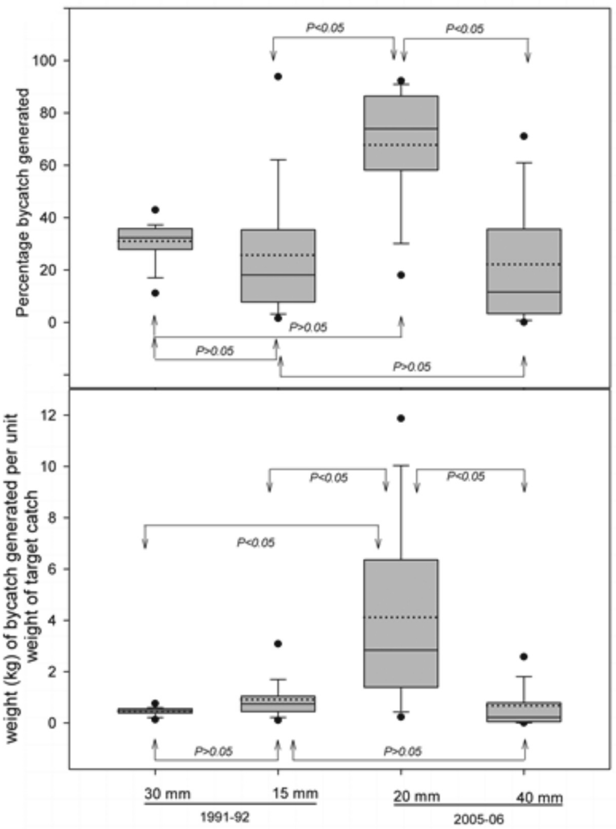


Fig. 1. Mean percentage of bycatch generated by different trawling systems during 1991-92 and 2005-06. Box limits correspond to 25th and 75th percentiles, whiskers correspond to 5th and 95th percentiles. Dots represent outliers thick continuous line is median and dotted line represent mean.

when 40 mm meshes were used during the years 2005-2006. The same effect is noticed in the trawling operations carried out during 1991-92, where the proportion of bycatch generated per unit of target catch was nearly halved when 30 mm codend meshes were used instead of 15mm mesh. This is due to the effect of large meshes used in the codend, which improve the selectivity of the gear (Bahamon et al., 2006; Broadhurst et al., 2000; He, 2007; Macbeth et al., 2007).

Contribution by the different species to total incidental catches is shown in Table 2. *Acetes* spp. and *Otolithes ruber* contributed a major share of the CPUE (kg $h^{-1}$) in the 15 and 30 mm codends used during 1991-92. Whereas *T. lepturus* and *Rhopilema* spp. were the major species contributed during 2005-05 in 20 and 40 mm codend mesh respectively. Both the *Rhopilema* spp and Hydromedusae were

Table 1. Results for the mean percentage of bycatch generated and weight of bycatch generated per unit weight of commercial catch

| Year | Mesh size | Percentage total incidental catch (Mean ± SE) | Weight (kg) of incidental catch generated per unit weight of commercial catch (Mean ± SE) |
|---|---|---|---|
| 1991-1992 | 15 mm | 25.69 ± 4.28[a,b] | 0.91 ± 0.13[a] |
| 1991-1992 | 30 mm | 31.03 ± 1.58[b,c] | 0.46 ± 0.03[a] |
| 2005-2006 | 20 mm | 67.77 ± 3.22[c] | 4.12 ± 0.58[b] |
| 2005-2006 | 40 mm | 22.15 2.44[a] | 0.67 ± 0.14[a] |

Means of the catches sharing the same superscript in a column are not significantly different (p>0.05)

Table 2. Top ten species in terms of biomass in the incidental catches for the different trawling systems used during 1991-92 and 2005-06

| 15mm (1991-92) | | 30 mm (1991-92) | | 20 mm (2005-06) | | 40 mm (2005-06) | |
|---|---|---|---|---|---|---|---|
| Species | CPUE (kg/hr) | Species | CPUE (kg/hr) | Species | CPUE (kg/hr) | Species | CPUE (kg/hr) |
| *Acetes* spp | 3.80 | *Otolithes ruber* | 1.24 | *Trichiurus lepturus* | 2.81 | *Rhopilema* spp | 4.34 |
| *Lepturacanthus savala* | 3.44 | *Thryssa dussumieri* | 1.23 | *Rhopilema* spp | 1.63 | *Otolithes cuvieri* | 0.63 |
| *Thryssa dussumieri* | 1.89 | *Otolithes cuvieri* | 0.89 | *Uroteuthis (P) duvauceli* | 0.45 | *Trichiurus lepturus* | 0.42 |
| *Uroteuthis (P) duvauceli* | 1.60 | *Uroteuthis (P) duvauceli* | 0.74 | *Hydromedusae* | 0.32 | *Otolithes ruber* | 0.32 |
| *Filimanus heptadactyla* | 1.35 | *Lactarius lactarius* | 0.60 | *Thryssa dussumieri* | 0.29 | *Hydromedusae* | 0.16 |
| *Calappa* spp | 0.98 | *Lepturacanthus savala* | 0.56 | *Otolithes cuvieri* | 0.28 | *Terapon theraps* | 0.16 |
| *Otolithes cuvieri* | 0.89 | *Calappa* spp | 0.48 | *Johnius glaucus* | 0.25 | *Lagocephalus spadecius* | 0.13 |
| *Apogon* spp | 0.89 | *Secutor insidiator* | 0.41 | *Terapon theraps* | 0.15 | *Acetes* spp | 0.11 |
| *Cynoglossus arel* | 0.74 | *Thryssa vitrirostris* | 0.35 | *Coilia dussumieri* | 0.13 | *Paranibea semiluctuosa* | 0.10 |
| *Grammoplites suppositus* | 0.71 | *Coilia dussumieri* | 0.25 | *Megalaspis cordyla* | 0.11 | *Opisthopterus tardoore* | 0.10 |

found to be absent in the top ten major contributing species in the incidental catches during 1991-92. The incidence of jellyfishes as indicators of ecosystem over fishing are reported (Mills, 2001; Pauly et al., 1998) and the increasing catches of jellyfishes in the landings of Veraval was reported by (Panda & Madhu, 2009). Another important observation is the declining trend of *Lepturacanthus savala* in the incidental catches in the recent years. This species was among the top five species in terms of biomass in the incidental faction during 1991-92, but was not observed among the important species in the incidental catches during 2005-06. The reduction in the CPUE of *Acetes* spp in the 20 mm codend during 2005-06 is also noted. High dominance in the contribution of individual species to the CPUE was observed during 2005-06. *Acetes* spp is one of the most important indicators of productivity and is the most important forage species in the lower trophic level which forms the food of commercially important species along the northwest coast (Deshmukh, 2002).

Different indices representing diversity for the incidental catches are shown in Table 3. Highest diversity was observed in 15 mm codend as indicated by both the indices of diversity S and d. Smith and Wilson Index ($E_{var}$) was calculated for the estimating the evenness, since this index was acknowledged to represent the evenness effectively (Magurran, 2004). Even though the value of Evar was higher in 20 mm codend, the difference between the trawling systems was not significantly different (p>0.05). With diversity as an additional factor in the

Table 3. Results of the diversity analysis of incidental catches generated by the different trawling systems during the years 1991-92 and 2005-06.

| Indices | 15 mm (1991-92) | 20 mm (2005-06) | 40 mm (2005-06) | 30 mm (1991-92) |
|---|---|---|---|---|
| S | 16 ± 0.80[a] | 9 ± 0.62[b] | 4.80 ± 0.32[c] | 12 ± 0.85[d] |
| (Total Species) | 15.93 (14.1 – 17.39) | 8.58 (7.46 – 9.8) | 4.78 (4.10 – 5.45) | 12.09 (10.64 – 3.68) |
| d | 7.89 ± 1.64[a] | 5.92 ± 0.62[a] | 5.91 ± 1.55[a] | 5.89 ± 0.53[b] |
| (Margalef) | 8.04 (5.59 – 11.93) | 5.92 (4.92 – 7.28) | 5.92 (3.29 – 9.50) | 5.86 (4.89 – 7.06) |
| H'(loge) | 2.06 ± 0.08[a] | 1.22 ± 0.05[b] | 0.69 ± 0.06[c] | 1.85 ± 0.07[d] |
| (Shannon–Wiener) | 2.07 (1.92 – 2.21) | 1.22 (1.12 – 1.30) | 0.69 (0.59 – 0.8) | 1.85 (1.71 – 2.01) |
| N1 | 8.70 ± 0.56[a] | 3.59 ± 0.19[b] | 2.32 ± 0.14[a] | 6.77 ± 0.50[a] |
| | 8.75 (7.78 – 9.89) | 3.59 (3.23 – 3.90) | 2.32 (2.06 – 2.59) | 6.76 (5.84 – 7.80) |
| N2 | 6.35 ± 0.49[a] | 2.59 ± 0.12[b] | 1.93 ± 0.11[a] | 4.90 ± 0.40[c] |
| | 6.39 (5.66 – 7.32) | 2.60 (2.38 – 2.80) | 1.93 (1.72 – 2.12) | 4.91 (4.06 – 5.81) |
| E var | 0.33 ± 0.02[a] | 0.43 ± 0.01[a] | 0.29 ± 0.06[a] | 0.30 ± 0.03[a] |
| (Smith-Wilson) | 0.33 (0.29 – 0.36) | 0.44 (0.41 – 0.46) | 0.29 (0.15 – 0.39) | 0.29 (0.24 – 0.34) |

Means of the indices sharing a common superscript in a row are not significantly different ($p>0.05$).The bootstrapped indices along with the 95 % CI of mean (in parenthesis) are also shown for each index.

evenness, the highest values for Shannon-Wiener (H'loge) index were observed for the 15 and 40 mm codend meshes. The results of Hill's indices of dominance pointed out highest dominance for 15 and 30 mm codend mesh respectively, meaning that relatively few species contributed to the total incidental catches in these trawling system (Jennings et al., 2001).

The years during which the data was collected were considered as factors for comparisons i.e., 1991-92 and 2005-06. The difference between the years was found to be significant at ($p<0.001$) and the Global 'R' value was 0.176. The same data matrix was used for comparison between the trawling systems used during different periods. Global R value noticed when the different trawling systems were compared was 0.19 ($p<0.001$) with 999 permutations. Pairwise tests between the assemblages in the different trawling systems were found to be significant except between the 30 and 40 mm codend mesh sizes. The highest dissimilarity was noticed between the 15 mm and 20 mm mesh size codend trawling system (R=0.826), followed by 20 mm and 30 mm codend mesh size (R=0.754) trawling system. Changes in the fish assemblage structure after intensive trawling and significant difference in the R values were noticed by (Gristina et al., 2006; Sánchez et al., 2004). Least difference was noticed between 20 and 40 mm assemblages (R=0.124) and between 30 and 40 mm (R=0.03).

Data matrix used for the ANOSIM analysis was subjected to non-metric multidimensional scaling (nMDS) to depict the separation of fish assemblages

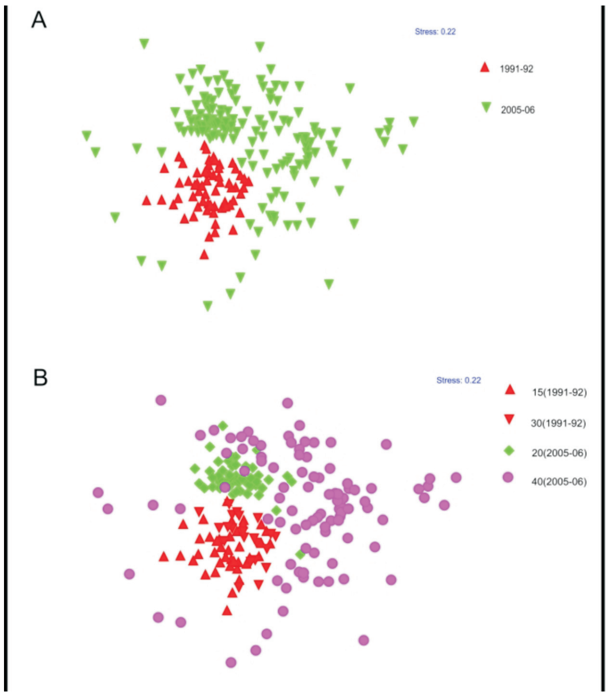


Fig. 2(A). Multi Dimensional Ordination showing dissimilarities among the bycatch assemblages during the years 1991-92

(B) The dissimilarity of bycatch assemblages between the different codends 15 and 30 mm (1991-92) and 20 and 40 mm codend (2005-06)

Table 4. Percentage contributions (>2.0%) of species to the average within- group similarity for the different trawling systems for two periods, identified using SIMPER analysis (Clarke, 1993; Clarke Warwick, 2001)

| Species | 1991-91 & 2005-06 (87.23 = Avg. Diss.) | 15 & 30 mm (69.17 = Avg. Diss.) | 15 & 20 mm (83.80 = Avg. Diss.) | 15 & 40 mm (90.64 = Avg. Diss.) | 20 & 30 mm (79.13 = Avg. Diss.) | 20 & 40 mm (86.06= Avg. Diss.) | 30 & 40 mm (88.55= Avg. Diss.) |
|---|---|---|---|---|---|---|---|
| Jellyfish | 3.36 | | | 4.69 | | 7.21 | 5.44 |
| *Lepturacanthus savala* | **5.38** | 3.16 | **4.96** | **5.46** | 5.23 | | 5.69 |
| *Thryssa dussumieri* | 4.30 | 3.93 | 3.07 | 3.95 | 4.27 | 6.20 | **6.03** |
| *Trichiurus lepturus* | 4.56 | | 8.36 | 2.32 | **9.10** | **12.87** | 3.21 |
| *Acetes* spp | 2.76 | 3.69 | 3.64 | 4.11 | | | |
| *Uroteuthis (P) duvauceli* | 4.56 | 2.66 | 3.16 | 4.67 | 3.61 | 7.73 | 6.03 |
| *Otolithes ruber* | 3.17 | **4.18** | | 2.42 | 4.57 | | 5.14 |
| *Otolithes cuvieri* | 3.04 | 3.18 | 2.78 | 2.49 | 3.91 | 4.65 | 3.86 |
| *Calappa* spp | 2.86 | 3.49 | 3.22 | 3.43 | | | |
| *Filimanus heptadactyla* | 3.41 | 3.38 | 3.47 | 3.73 | 2.70 | | 3.11 |
| *Lactarius lactarius* | 2.58 | 3.45 | | | 3.95 | | 4.24 |
| *Grammoplites suppositus* | | | | | | | |
| *Coilia dussumieri* | 2.21 | 2.63 | 2.36 | | 3.25 | 3.34 | 2.91 |
| *Cynoglossus* spp | | 2.20 | | 2.02 | | | |
| *Secutor insidiator* | 2.53 | 2.89 | | 2.10 | 3.26 | | 3.47 |
| *Thryssa vitirostris* | | 2.81 | | | 3.06 | | 3.26 |
| *Johnius glaucus* | | | 3.04 | | 3.55 | 4.95 | |
| Hydromedusae | | | | | | 3.39 | |
| *Terapon theraps* | | | | | | | |
| *Loliolus* spp | 2.38 | 2.79 | 2.51 | 2.69 | | | |
| *Lagocephalus* spp | 2.98 | 2.71 | 2.44 | 3.19 | 2.30 | 3.17 | 3.40 |
| *Sepia aculeata* | | 2.55 | | | 2.31 | | 2.42 |
| *Nemipterus japonicus* | | 2.37 | 2.13 | 2.29 | | | |
| *Johnius dussumieri* | | 2.30 | | | | | |
| *Metapenaeus stridulans* | | 2.23 | 2.11 | 2.27 | | | |
| *Saurida tumbil* | | | 2.21 | 2.09 | | 2.33 | |
| *Megalaspis cordyla* | | | | | 2.27 | 3.28 | |

in the different trawling systems collected during 1991-92 and 2005-06 in a 2-dimensional space. Results of the MDS were in concurrence with the findings of the ANOSIM, where the assemblages of the incidental catches during 1991-92 formed a close group and incidental catches generated during 2005-06 was shown separated from the assemblages of 1991-92 with more dispersion (Fig. 2). The stress for the ordination was 0.22 for two-dimensional depiction, which is a fairly good representation showing separation evident between the different assemblages (Gamito & Raffaelli, 1992; Lane & Brown, 2007).

Data was fourth-root transformed and standardized for the similarity percentage analysis (SIMPER). The species contributing to more than 2% for the dissimilarity between the assemblages are shown in table 2. Average dissimilarity between the bycatch assemblages during the years 1991-92 and 2005-06 was noticed to be 87.23 %. *L. savala* (5.38) and *T. lepturus* (4.56) contributed the most to the between assemblages dissimilarity in incidental catches between the years. The least dissimilarity was observed between 15 and 30 mm codend mesh assemblages (69.17) and the highest dissimilarity was noticed between 15 and 40 mm codend mesh assemblages (90.64). *Otolithes ruber*, *T. dussumieri* and *Acetes* spp. were the major species contributing to the dissimilarity between the assemblages of 15 and

30 mm codend, whereas *L. savala*, jellyfish and *Uroteuthis (P) duvauceli* were the major species that differentiated the assemblages between 15 and 40 mm codends.

Lower and higher dissimilarity among the assemblages between 15 and 30 mm and 15 and 40 mm codend meshes suggest the availability and exploitation of fishes of similar nature during different periods (Westera et al., 2003). Juveniles of *O. ruber*, *T. dussumieri* and *Acetes* spp. contributed the most to dissimilarity and *T. dussumieri* and *Acetes* spp. were considered as low value species. The highest dissimilarity was observed between the assemblages of 15 and 40 mm mesh size and jellyfish, *U. (P) duvauceli* and *L. savala* contributed the most to the dissimilarity. This shows the decline in the catches of *L. savala* during 2005-06 and the emergence of jellyfish as an important species in the ecosystem during this period, when the contribution by the different species is considered (Table 2). The most important species contributing to the dissimilarity (86.06) between the species retained in the 20 and 40 mm codends was *T. lepturus* and this was due to the contribution of large amounts of juveniles in the 20 mm codend (CPUE = 2.81 kg $h^{-1}$). In case of 40 mm the average CPUE recorded for the species was only 0.42 kg $h^{-1}$. *Rhopilema* spp. was recorded in both the trawling system in large quantities. Decline in the catches of *T. dussumieri*, which contributed significantly during 1991-92 was also noticed during 2005-06.

It is evident from the findings that there is a perceptible change in the proportion and assemblage structure of the bycatch generated by the different trawling systems over the years off Veraval coast. This study also shows the benefits of increasing the mesh size of the codend as a technical measure to reduce bycatch. More controlled experiments with different mesh sizes for characterizing the incidental assemblage and partitioning the effects of parameters related to gear and environmental variables will help in understanding the changes in assemblage structure of the trawl resource in Gujarat waters.

## Acknowledgement

The authors would like to thank the Director, ICAR-Central Institute of Fisheries Technology for granting permission to carry out the work. The help rendered by the crew of MFV Sagarkripa in collecting data is acknowledged.

## Supplementary Information

Vertical and horizontal openings of the trawl net for the purpose of normalizing catches were worked out using the methods given in Prado, 1990. The vertical spread in meters for the trawl net was derived by the equation ***V=2.N.a.0.06***, where *N*= width in number of meshes of the front of the belly, *a*= mesh size in meters of single mesh. The horizontal spread of the net (*H*) was derived as ***HR.0.5***, where HR is the length of the head rope of the trawl in meters. Scaling factor (s) = surface area of net 1/surface area of net 2.

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