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Studies on the Preponderance of Jellyfish in Coastal Waters of Veraval

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Ascendance pattern of jellyfish biomass in coastal waters off Veraval was investigated. Jellyfish landing figures obtained from four different trawling systems viz. 18m semipelagic trawl with 70mm codend mesh size (SP70), 18m semipelagic trawl with 50mm codend mesh size (SP50), 34m bottom trawl with 60mm codend mesh size (BT60) and 34m bottom trawl with 40mm codend mesh size (BT40) during 2005-06 was used for the analysis. The average percentage contribution of jellyfish varied from 9.7-23.8% in different trawling systems. Exclusion of non-jellyfish hauls revealed highest jellyfish capture (91%) by SP70 and more than 22% in all the trawling systems. The frequency of occurrence of jellyfish was highest in BT40. Estimation of seasonal variation in jellyfish landings showed higher catch during post-monsoon period i.e. 25% considering all hauls and 63% after excluding non-jellyfish hauls. Jellyfish formed higher component of bycatch during pre-monsoon. Juveniles of commercially important species like cephalopods, sciaenids and ribbon fishes were found to have higher degree of association with jellyfish.

Key words : Jellyfish, bycatch, degree of association, trawling System

In the recent years ascendance of jellyfish population in coastal waters is becoming increasingly common (Mills, 2001) with concomitant impact on ecosystem functions, including diversity. Jellyfishes, commonly referred to the medusae of the phylum Cnidaria and planktonic members of the phylum Ctenophora exhibit wider fluctuation in biomass in response to anthropogenic perturbations or changing oceanographic conditions such as eutrophication (Arai, 2001), hypoxia (Purcell et al, 2001) and climate induced regional regime shift (Brodeur et al., 1999). Severe fishing pressure impacting trophic level changes such as decline in large predatory fishes and simultaneous increase in plankton feeders and low trophic level invertebrates like jellyfish has been explained by the famous theory of "fishing down marine food web" (Pauly et al., 1988; Pauly et al., 2002). Proliferation of gelatinous zooplankton species like jellyfish not only exerts a profound ecosystem change, but also impedes the recovery of exploited fish population after cessation of fishing, as they heavily devour upon the fish eggs and larvae (Lynam et al., 2005).

In Indian waters, there are scant reports on jellyfish populations, their role in coastal ecosystem or consequential increase in heavily exploited regime; although a significant decrease in mean trophic index of the landed fish species has been reported (Bhathal, 2004). Masilamoni et al. (2000) reported three species of jellyfish, namely *Crambionella stuhlmanni*, *Chiropsoides buitendijki* and *Dactylometra quinquicirrha* predominant along Madras waters. Processing of edible jellyfishes for export market, especially from Tamil Nadu coast has been reported (Kuthalingam et al., 1989; Manickaraja and Balasubramanian, 2006), which gives an indirect account of jellyfish availability in those waters.

Veraval situated at 20°54'N latitude and 070°22'E longitude in the north-west coast of India is a premier landing centre contributing to about 25.08% of the total marine fish

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landings of the state of Gujarat (Anon, 2005). During the last decade, fishing overcapacity and extensive trawling over coastal waters has not only elicited a decline in catch per unit effort, but also a gradual shift in community diversity The average catch per boat per year has come down from about 150 t to less than 40 t in the late nineties and comparatively low economic value species comprise 75% of the total landings in Gujarat (Nair et al., 2003). As jellyfish species are often noticed in the catch, there is a need to investigate any correlation between increasing signs of overexploitation and preponderance of jellyfish in Veraval waters. In this study the landing patterns of jellyfish in different trawling units, their seasonal variation and association with other cohabiting species are highlighted.

Material and Methods

Experimental trawling was conducted off Veraval coast by the departmental fishing vessel MFV Sagarkripa. The trawling operations were carried out in the coastal waters up to a depth of 50m. Data obtained from four different trawling systems were used for this study. Two of them were 34m high opening bottom trawls with 40mm and 60mm codend mesh size and fitted with a pair of V-form otterboards (79x136cm; 85 Kg each). The other two trawling systems used were 18m semipelagic trawl with 40mm and 70mm codend mesh size and fitted with a pair of Suberkrub otterboards (115x89 cm; 90 kg each). The trawling speed was maintained at 2.0-3.0 knot for bottom trawling and 2.5-3.5 knot for semipelagic trawling. Different trawling systems were designated as BT40 and BT60 (codend of 40mm and 60mm mesh size respectively) for bottom trawls and SP50 and SP70 (50mm and 70mm codend mesh sizes respectively) for semipelagic trawls.

The study was conducted from Jan 2005 to Dec 2006, except during the official fishing ban period (May-August). Constant gear settings and retrieval procedures were adopted to reduce variability in the operations. The order of selection of trawling systems for the experiment was randomized to avoid bias in analysis. All the catch data were standardized to one hour tow duration. The total catch and total bycatch obtained in each haul was estimated. Similarly, Jellyfish retained in codends were segregated, weighed and taxonomically identified.

Average percentage contribution of jellyfish in different trawling systems was estimated separately for all hauls. Kruskal-Wallis one way analysis of variance on ranks was used to determine significant difference in mean jellyfish percentage contribution in different trawling systems. The catch per unit effort for jellyfish in different trawling systems were estimated and compared with that of the total catch for the respective gears. Frequency of occurrence of jellyfish was determined by taking the reciprocal of number of hauls where jellyfish was encountered with the total number of hauls undertaken for each trawling system. The values were expressed as percentage and tabulated.

Seasonal variation in jellyfish capture was estimated by classifying the hauls into two groups: pre-monsoon (Jan-May) and post-monsoon (Sep-Dec). Catches from hauls of all trawling systems were pooled together and compared. The mean percentage of jellyfish contribution in total catch and bycatch was calculated separately for both the seasons. Significant difference in seasonal landings of jellyfish was determined with Kruskal-Wallis Test (a nonparametric test alternative to one-way ANOVA). The seasonal variation in jellyfish landings were depicted in the form of Box plots where box limits correspond to 25th and 75th percentiles, whiskers correspond to5th and 95th percentiles and mid-box line to median. In this study, Kruskal-Wallis Test was carried out by using SPSS software (version 12.0.1) and box plots by using Sigmaplot (10.0),

The association of other species with jellyfish was determined in hauls where jellyfish contributed more than 40% of the total catch. In these selected hauls for each trawling system, the figures of associated species (in weight) were converted to presence or absence value i.e. 1 for presence and 0 for absence. The degree of association of each species with jellyfish was calculated by taking the reciprocal of sum of all presence values with sum of number of hauls in each trawling system. The value ranges from 0 to 1, where 0 value indicates no association and 1 indicates complete association.

Results and Discussion

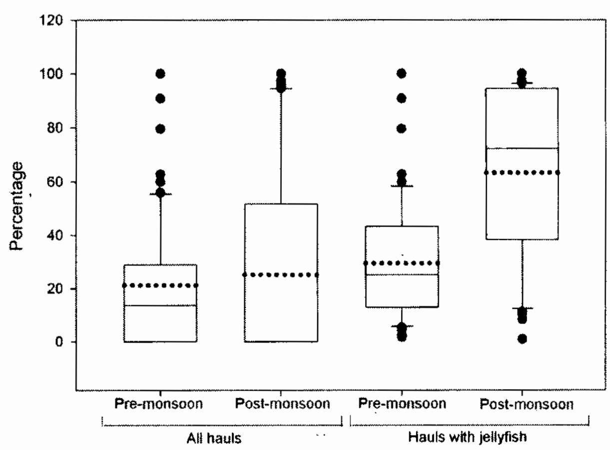
The species of jellyfish mostly encountered in the experimental trawling system of Veraval were scyphozoid *Rhopilema esculentum* Kishinouye, 1891, cubozoid *Chiropsoides buitendijki* (Horst, 1907) and hydromedusae *Aequorea* sp. There might be many other diverse groups, as taxonomic status of all jellyfish species could not be ascertained all the time because of complications involved in their identification and paucity of information about their distribution in Arabian Sea. Taxonomy of jellyfishes is considerably confused due to their extremely large size and difficulty in preservation for taxonomic studies (Omori and Kitamura, 2004). Some jellyfish species like *Crambionella stuhlmanni, Chiropsoides buitendijki, Chrysaora quinquecirrha* and *Rhopilema esculentum* are reported to be present in Indian waters (MPEDA, 2002). Similarly, in Pakistan waters, which is in close proximity with Gujarat coast, commercial fishing and processing of jellyfish species like *Rhizostoma pulmo, Chiropsalmus buitendijki* and *Catostylus mosaicus* have been reported (Tahera and Kazmi, 2006; Muhammed and Sultana, 2007). In South East Asian waters, especially in the tropical Indo-West Pacific region, fisheries of 11 edible jellyfish species belonging to families Cepheidae, Catostylidae, Lobonematidae, Rhizostomatidae and Stomolophidae are reported (Omori and Nakano, 2001).

The average contribution of jellyfish in different trawling systems varied from 9.72 ± 2.79% to 23.78 ± 5.03% (Table 1), when all hauls were considered. Jellyfish was not encountered in all the hauls of different trawling systems, calculation of average percentage contribution in jellyfish encountered hauls showed a substantially highervalues. In semipelagic trawl with 70mm codend mesh size (SP70), jellyfish contributed to the most (around 91%), and the mean percentage contribution was found to be significantly different (P<0.05) from that in other trawling systems. Although the average percentage contribution of jellyfish in BT60 was higher than that of SP50, there was no significant difference in their mean values. These results show that although the jellyfish landings are more than 22% of the total catch, the mode of capture i.e. use of

Table 1. Average percentage contribution of jellyfish in different trawling systems

Trawling System	Percentage contribution of jellyfish (Mean ± S.E.)	
	All hauls	Hauls with jellyfish
SP70 (n=65)	23.78 ± 5.03	90.91 ± 2.25[a]
BT60 (n=51)	17.91 ± 4.18	53.72 ± 6.62[b]
SP50 (n=33)	9.72 ± 2.79	22.90 ± 4.67[b]
BT40 (n=106)	19.77 ± 2.77	40.30 ± 4.0[c]

* n, number of hauls
**Means sharing the same superscript are not significantly different from eachother (Dunn's method, P<0.05)



* Box limits correspond to 25th and 75th percentiles, whiskers correspond to 5th and 95th percentiles and dotted line indicates mean. Dots indicate extreme values.

Fig. 1. Seasonal variation in jellyfish landings: percentage of total catch

Table 2. CPUE of Jellyfish vs total CPUE of the gear

Trawling System	CPUE of Jellyfish (Mean ±S.E.) (Kg. Hour $^{-1}$)	Range of Jellyfish catch (Kg. Hour^{-1})	Total CPUE of the gear(Mean ±S.E.) (Kg. Hour $^{-1}$)
SP70	19.65±3.51^{a}	2.0-50.0	20.77±3.58^{a}
BT60	5.54±2.04^{b}	0.11-30.0	8.06±2.3^{b}
SP50	3.64±1.12^{c}	0.3-14.12	16.69±3.04^{a,b}
BT40	10.38±2.20^{b}	0.12-60.0	21.88±2.91^{c}

*Means sharing the same superscript are not significantly different from each other (Dunn's method, $P<0.05$)

a particular design of trawl and its operational characteristics heavily influences the retention of jellyfish. High retention in semipelagic trawls with a comparatively bigger codend mesh size (i.e. 70mm) may be ascribed to the off bottom positioning of the gear while towing with low drag conditions (Brewer et al., 1996) as well as habitat preference of jellyfishes. It is known that medusae of some species of jellyfish like *Pelagia noctiluca* form subsurface aggregations and exhibit characteristic foraging behaviour (Malej, 1989).

Similar to the above findings, the highest jellyfish CPUE was observed in SP70 (19.65±3.51, mean ± s.e., kg. Hour^{-1}), followed by BT40, BT60 and SP50 trawling systems (Table 2). The high incidence of jellyfish in some of the trawling systems can be understood by comparing the CPUE of the jellyfish with the corresponding mean CPUE of the gear. In BT40 system, sometimes jellyfishes weighing upto 60Kg were observed in one hour towing operation. Another observation was that catch of jellyfish in semipelagic trawls were significantly different than that of bottom trawls ($P<0.05$), implying type of gear influencing the jellyfish catch.

The gear-wise frequency of occurrence of jellyfish as depicted in Table 3 showed highest jellyfish occurrence (49.06%) in BT40. As bottom trawls with less than 40mm mesh size codend are being operated predominantly in Veraval waters, the chance of encountering meduase of jellyfishes is very high.

Seasonal variation in jellyfish landings was estimated by pooling together the catch figures of all trawling systems into two seasonal groupings viz. pre-monsoon (Jan-May) and post-monsoon (Sep-Dec). As shown in Fig.1, taking into account the data from all hauls, the post-monsoon catch of jellyfish was 25.07 ± 3.12 % of the total catch, which was higher than that of pre-monsoon (21.11 ± 2.72 %). While considering the hauls, only where jellyfish was encountered in the catch, similar trend was observed. In both the cases the Kruskal-Wallis test revealed significant difference ($P<0.05$) in pre-monsoon and post-monsoon landings of jellyfish. Higher jellyfish landings during post-monsoon period might be due to higher nutrient loading from land run-off during monsoon leading to localized eutrophication in coastal waters. Jellyfishes becoming the most abundant species during excessive eutrpohication stage in Seto inland sea and simultaneous reduction in abundance of other fish species have been reported by Nagai (2003). While investigating the factors that might have caused an increase of jellyfish populations in the Mediterranean sea, Legovic (1987) had reported higher nutrient inflow causing an increase in the steady state of jellyfish population.

Table 3. Gear-wise frequency of occurrence of jellyfish

Trawling System	% of occurrence
SP70	26.15
BT60	33.33
SP50	42.42
BT40	49.06

As bycatch forms significant component of catch in Veraval waters and jellyfishes are frequently discarded onboard because of their poor market price and problems in preservation, estimations were also made for percentage contribution of jellyfish of total bycatch for different seasonal groupings. As depicted in Fig.2, considering all hauls, jellyfish formed a higher component of bycatch during pre-monsoon period i.e. 54.49 ± 4.67% than during post-monsoon (32.97 ± 3.68%). Excluding non-jellyfish hauls, the post-monsoon average percentage contribution of jellyfish to the bycatch (83.31 ± 3.15%) scored higher than that of pre-monsoon (76.08 ± 3.35%). The Kruskal-Wallis test also revealed significant difference ($P<0.05$) in percentage contribution of jellyfish in total bycatch during pre-monsoon and post-monsoon. The post-monsoon jellyfish plus hauls had higher incidence of small sized juveniles of commercially important finfish and shellfish species. In an earlier study, Pravin and Manohardoss (1996) had reported higher incidence of juveniles of commercially important finfish and shellfish species in the low value trawl bycatch caught off Veraval.

The degree of association of species gives an indirect account of the level of trophic interaction and niche differentiation taking place in an ecosystem. It was

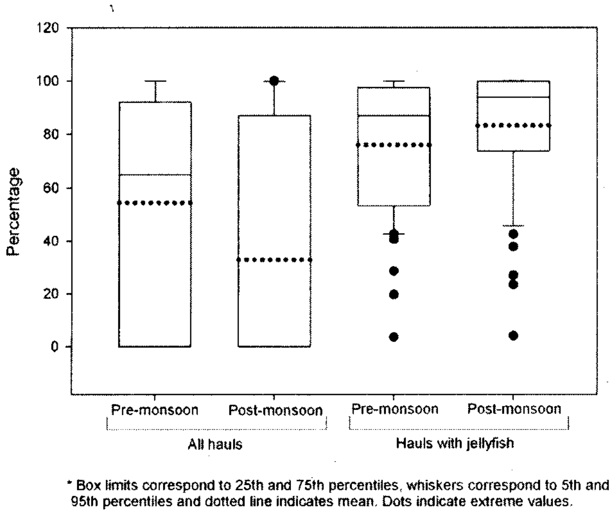


Fig. 2. Seasonal variation in jellyfish landings: percentage of total bycatch

observed in Benguela region of Namibia that jellyfishes proliferate in heavily exploited fishing regime (Lynam *et al.*, 2006). In the present study an attempt was made to find such species that might be showing some coexistence with jellyfish. Hauls from four different trawling systems where jellyfishes contributed more than 40% of the catch were taken into consideration and species that had degree of association value more than 0.05 are shown in Table 4. In this study we consider a value of ≥ 0.5 as average association and ≥ 0.7 as high level association. In BT40, *Trichiurus lepturus, Sepiella inermis* and *Thryssa dussumieri* had average association, whereas *Uroteuthis (Photololigo) duvauceli* had high level of association over the duration of the study. In BT60, *Uroteuthis (Photololigo) duvauceli, Thryssa dussumieri, Coilia dussumieri* and *Johnius glaucus* showed average level of association and two species *Trichiurus lepturus* and *Otolithes cuvieri* had high level of association with jellyfish. In SP50, 5 different species *Lactarius lactarius, Scomberomorus guttatus, Sepiella inermis, Trichiurus lepturus* and *Uroteuthis (Photololigo) duvauceli* had high level of association and 7 species *Alepes kleinii, Carangoides talamperoides, Dussumieria acuta, Gazza minuta, Opisthopterus tardoore, Otolithes cuvieri* and *Otolithes ruber* had average level of association. But, in SP70 none of the species had average level of association with jellyfish. These findings suggests that most of the time jellyfishes are associated with commercially important species landed in this region like cephalopods, sciaenids and ribbonfish. Present study showed jellyfishes predominated along with juveniles of the commercially important species. As jellyfishes devour upon larvae and juveniles of fishes, ascendance of jellyfish population when new recruits of commercially important species are in the ground may further exacerbate the condition of the fishery and augment to already existing heavy fishing pressure prevailing in the ecosystem. Inverse relationships between abundances of scyphomedusae (Cnidaria: Scyphozoa) and ichthyoplankton

Table 4. Degree of association of different species with jellyfish

Species	BT40	BT60	SP50	SP70
Alepes djedaba				0.06±0.06
Alepes kleinii	0.09±0.06		0.50±0.29	0.18±0.10
Anodontostoma chacunda		0.08±0.08		
Arius tenuispinis		0.08±0.08		
Atropos atropus			0.25±0.25	
Atropus atropos				0.06±0.06
Carangoides talamparoides	0.09±0.06			
Carangoides talamparoides			0.50±0.29	
Charybdis (charybdis) feriatus		0.17±0.11		0.06±0.06
Charybdis feriatus	0.09±0.06			
Cociella crocodila				0.06±0.06
Coilia dussumieri	0.14±0.07	0.50±0.15		
Decapterus russelli	0.09±0.06			
Dussumieria acuta	0.14±0.07		0.50±0.29	
Encrasicholina devisi		0.08±0.08		
Epinephelus diacanthus	0.14±0.07	0.08±0.08		
Filimanus heptadactyla	0.14±0.07			
Gazza minuta	0.14±0.07		0.50±0.29	
Harpadon nehereus	0.14±0.07		0.25±0.25	
Ilisha megaloptera	0.09±0.06			0.06±0.06
Johnius borneensis	0.14±0.07			
Johnius dussumieri			0.25±0.25	
Johnius glaucus	0.32±0.10	0.50±0.15		0.12±0.08
Johnius macrorhynus		0.08±0.08		
Lactarius lactarius	0.23±0.09		0.75±0.25	
Lagocephalus spadiceus	0.23±0.09			
Leiognathus equulus			0.25±0.25	
Lepturacanthus savala	0.18±0.08			
Lethrinus nebulosus				0.12±0.08
Lutjanus johni				0.18±0.10
Megalaspis cordyla		0.08±0.08	0.25±0.25	0.18±0.10
Metapenaeus affinis		0.08±0.08		
Metapenaeus monoceros		0.08±0.08		
Opisthopterus tardoore	0.36±0.10	0.17±0.11	0.50±0.29	
Oratosquilla nepa		0.08±0.08		
Otolithes cuvieri	0.27±0.10	0.75±0.13	0.50±0.29	
Otolithes ruber	0.14±0.07		0.50±0.29	
Pampus argenteus	0.18±0.08	0.42±0.15		0.06±0.06
Parapenaeopsis stylifera	0.18±0.08			
Parastromateus niger	0.14±0.07	0.08±0.08	0.25±0.25	0.35±0.12
Pennahia anea	0.09±0.06			0.18±0.10
Pomadasys maculatus			0.25±0.25	
Portunus pelagicus				0.06±0.06
Portunus sanguinolentus		0.17±0.11		0.12±0.08
Protonibea diacanthus				0.06±0.06
Psettodes erumei				0.12±0.08
Pumpus argenteus		0.08±0.08		
Rastrelliger kanagurta	0.09±0.06	0.08±0.08		0.12±0.08
Saurida tumbil				0.06±0.06
Scomberomorus commerson				0.06±0.06
Scomberomorus guttatus			0.75±0.25	0.24±0.11
Sepia pharaonis				0.06±0.06
Sepiella inermis	0.64±0.10	0.42±0.15	0.75±0.25	
Sphyraena forsteri	0.14±0.07			
Sphyraena obtusata				0.06±0.06
Stolephorus indicus	0.09±0.09			
Thenus orientalis				0.06±0.06
Thryssa dussumieri	0.59±0.11	0.58±0.15		
Thryssa mystax	0.09±0.06			
Tibia curta		0.08±0.08		
Trachypenaeus curvirostris	0.09±0.09			
Trichiurus lepturus	0.68±0.10	0.83±0.11	0.75±0.25	0.35±0.12
Upeneus vittatus			0.25±0.25	
Uroteuthis (Photololigo) duvauceli	0.77±0.09	0.67±0.14	0.75±0.25	0.18±0.10

* Hauls contributing jellyfish more than 40% of total catch are only considered
** Species with degree of association more than 0.05 are only shown

or zooplankton have been documented in various locations across the globe (Möller, 1984; Behrends and Schneider, 1995; Omori et al., 1995; Purcell and Sturdevant, 2001).

As evident from the results, proliferation of jellyfishes in coastal waters can be suggestive of existing health of a fishery. Studies on abundance and distribution of jellyfish in coastal waters can provide important baseline information for ecosystem models and can be used to help evaluate impacts of jellyfish blooms in coastal upwelling regions (Suchman and Brodeur, 2005). Persistence patterns of association of different species with jellyfish, supported with time-series data and additional biological information can be used in trawl impact studies.

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