



Elasmobranch diversity, conservation and management along Wadge Bank, South India

K. Karuppasamy*, P. Jawahar, S. David Kingston, V.K. Venkataramani¹ and V. Vidhya

Fisheries College and Research Institute,

Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Tuticorin-628 008, Tamilnadu, India.

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ABSTRACT

The study was undertaken to document the elasmobranch diversity and their abundance along Wadge Bank. Species were collected fortnightly during June 2015 to May 2016 from three landing centres viz., Chinnamuttom, Colachel and Vizhinjam of Wadge Bank. A total of 1,575 specimens were collected during the period and 44 species were identified belonging to 8 orders, 13 families and 25 genera. Among the recorded families, Carcharhinidae is the most dominant family with 12 species. The Colachel landing centre was rich in diversity with 43 species followed by Chinnamuttom 39 species and Vizhinjam 26 species. The highest Shannon Weiner diversity (H' value) was observed at Colachel (4.17) followed by Chinnamuttom (4.11) and Vizhinjam (3.76). The Margalef's species richness ('d') value was assessed at Colachel (4.55) followed by Chinnamuttom (4.01) and Vizhinjam (2.91). The Pielou's evenness (J') estimated was 0.7786, 0.7700 and 0.8005 respectively, for Chinnamuttom, Colachel and Vizhinjam. The highest taxonomic diversity value was observed at Colachel (60.33) and the lowest during at Vizhinjam (54.08). Among the three landing centres studied, the total phylogenetic diversity (sPhi+) was found to be the lowest at Vizhinjam (940) and highest at Colachel landing centre (1720). Bray Curtis similarities measure was also calculated, fish communities were separated into several clusters based on seasons. The conservation of elasmobranchs and the management measures to be followed along the Wadge Bank is also discussed.

Key words: Biodiversity indices, Elasmobranch diversity, South east and South west coast of India.

INTRODUCTION

Chondrichthyans are one of the major capture fishery resources of Indian EEZ and are being exploited by different types of crafts and gears for decades. One of the earliest compilations of chondrichthyan diversity in Indian waters was done by Day (1889) who reported 69 species. Raje *et. al.*, (2002) listed 110 elasmobranch species from the Indian Seas. Raje *et. al.*, 2007 listed 84 species of elasmobranchs occurring in the Gulf of Mannar. Recent compilation of Akhilesh *et. al.*, (2014), indicated that 227 species of elasmobranchs from Indian seas and the diversity is higher than reported in many other tropical Ocean countries. South Cape Comorin has been generally known as the 'Wadge Bank' defined by the Fishery Survey of India. The area is about 4000 Sq. miles and a rich biodiversity of finfishes has been reported in this region and it is a fertile fishing ground (Mitra, 1987).

Detailed study on the elasmobranchs diversity pertaining to its taxonomy, abundance and species richness has not been carried out along the Wadge Bank. Previous studies were in the form of reports pertaining to their occurrence and fishery. It is also worthwhile to mention that among the species recorded two species of sharks and two species of rays are reported under IUCN Red list Endangered

category. A comprehensive study emphasising its occurrence, species diversity, species richness, taxonomic diversity and Phylogenetic diversity was attempted using the PRIMER V6 software for a period of one year along this coast. The study is first of its kind and such a study in this coast using the software has not been attempted so far.

MATERIALS AND METHODS

Wadge Bank is situated in the Southern tip of India. It lies between 76° 30'E to 78° 00 E Long, and 07° 00, to 8° 20' N Lat (Fig 1) from Kanyakumari to Vizhinjam having approximately 4000 sq. Miles. It is situated between southeast and southwest coast of India with majority of area in southwest coast. The present study was carried out for a period of 12 months from June 2015 to May 2016 in three major fish landing centres of Wadge Bank viz., Chinnamuttom, Colachel and Vizhinjam. Mainly Chinnamuttom lies in South east coast of India while Colachel and Vizhinjam lies in South west coast of India.

From these selected landing centres information on crafts specifications, (types of trawlers) gears specifications (head rope length, type of otter board and cod end mesh size), fishing operation details (depth of operation, trawling hour, towing and hauling speed) and accessories, species diversity data were collected. In Chinnamuttom and Colachel

*Corresponding author's e-mail & address: karuppasamyfsc@gmail.com; Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University, Tuticorin-628 008, Tamilnadu, India.

¹Kerala University of Fisheries and Ocean Studies, Panangad, Kochi, Kerala, India.

landing centres the trawl nets were operated for fishing, while in Vizhinjam the fishery is exclusively Non-motorized. The diversity and community structure of the elasmobranchs species were analyzed. Geographical position of each sampling station of Chinnamuttom (Lat. 8°05'52" N, Long. 77°33' 50" E), Colachel (Lat. 8°10' 17" N, Long. 77°15' 11" E) and Vizhinjam (Lat. 8°10' 173 N, Long. 77°152 113 E) was recorded with Global Positioning System (GPS). The total catch, length range and catch composition of elasmobranch species were recorded. For identifications of species, standard taxonomical books and manuals were used (Misra, 1969; Compagno, *et. al.*, 1984; Venkataraman, *et. al.*, 2003 and Eschmeyer, 2014).

A suite of statistical approaches was carried out for the simplification and elucidation of the biological data. For convenience, statistical techniques of different biodiversity indices were calculated using PRIMER v.6 (Plymouth Routines In Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory (Clarke and Warwick, 1998; Clarke and Gorley, 2001).

RESULTS AND DISCUSSION

Check list of Elasmobranchs: In the present study, a total of 44 species belonging to 8 orders, 13 families and 25 genera were recorded from Wadge Bank (Table 1). The elasmobranchs are represented in 8 orders, of which Myliobatiformes contributed 36.4% with 17 species followed by Carcharhiniformes with 34.1% having 15 species and Rajiformes 11.4%, with 3 species (Fig 2). Among the 13 families recorded, Carcharhinidae is the dominant family with 12 species followed by Dasiyatidae 9 species and Myliobatidae with 5 species. A check list of elasmobranch diversity, its occurrence and with detailed taxonomic position is presented in Table 1. Earlier studies by Theivasigamani and Subbiah (2014) reported 65 species of elasmobranchs at Thoothukudi coast, indicated the dominance of Myliobatiformes and Carcharhiniformes with 49.23% and 32.31% respectively. Gowthaman (2011) reported 72 elasmobranch species belongs to 6 orders, 21 families and 42 genera from Gulf of Mannar, South east coast of India. Rajiformes was found to be the dominant order followed by Carcharhiniformes (28) and Orectolobiformis (6).

High species richness was observed in Colachel with 43 species represented by 12 families, of which the family Carcharhinidae is with 12 species followed by the family Dasiyatidae with 9 species and Myliobatidae with 4 species. In Vizhinjam the lowest species richness was recorded. A total of 26 species was represented by 9 families. Of the recorded 44 species, four are under endangered list and twelve species are under vulnerable list (IUCN, 2018) (Fig 3).

Biodiversity indices of elasmobranchs: Spatio-temporal variability in biodiversity indices such as Shannon – Wiener species diversity ($H'(\log_2)$), Margalef's species richness (d), Pielou's evenness (J'), Taxonomic diversity (Δ), Taxonomic

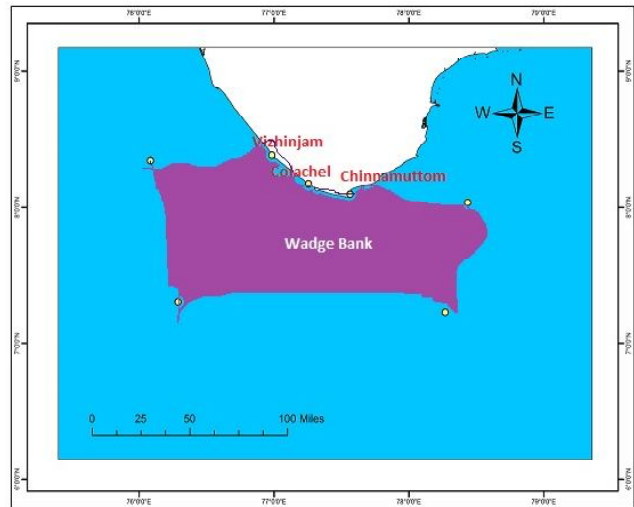


Fig 1: Map showing the Study Area of Wadge Bank, South India.

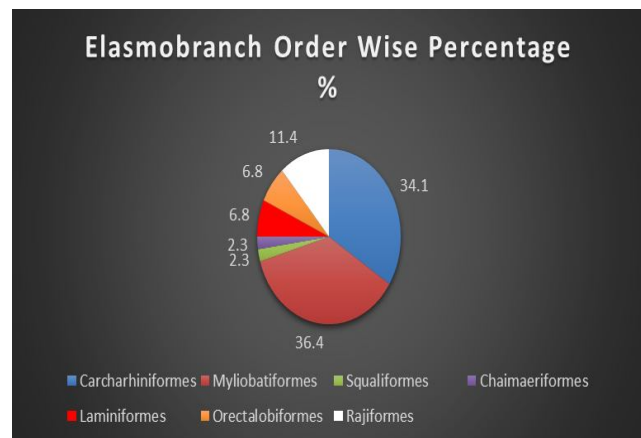


Fig 2: Order wise elasmobranch percentage composition.

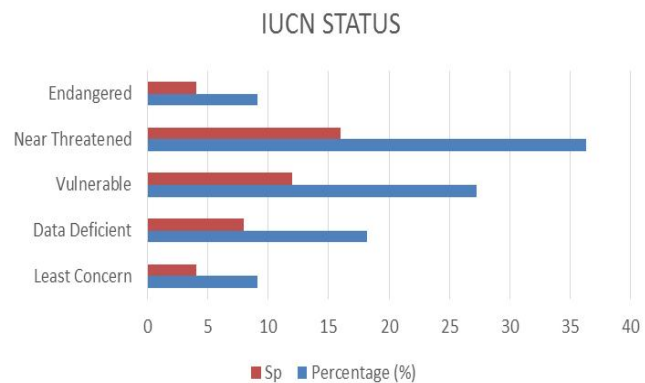


Fig 3: IUCN Status for elasmobranch diversity along South India.

distinctness (Δ^*) and Total Phylogenetic diversity ($sPhi+$) were calculated using PRIMER Version 6.

Species richness: The spatial variation in 'd' value is given in Table 2. The highest ('d') value was observed at Colachel (4.55) followed by Chinnamuttom (4.07) and lowest value was observed in Vizhinjam (2.91).

Table 1: Check List of Elasmobranch Diversity of Wadge Bank, South India.

Order	Family	Species	CM	CL	V	IUCN
Lamniformes	Alopiidae	<i>Alopias pelagicus</i>	+	+	-	VU
Lamniformes	Alopiidae	<i>Alopias superciliosus</i>	+	+	+	VU
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus amblyrhynchos</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus amboinensis</i>	+	+	-	DD
Carcharhiniformes	Carcharhinidae	<i>Carcharhinusbrevipinna</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus dussumieri</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus falciformis</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus limbatus</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus macloiti</i>	+	+	-	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus melanopterus</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Carcharhinus sorrah</i>	+	+	+	NT
Carcharhiniformes	Carcharhinidae	<i>Galeocerdo cuvier</i>	+	+	-	NT
Carcharhiniformes	Carcharhinidae	<i>Rhizoprionodon acutus</i>	+	+	+	LC
Carcharhiniformes	Carcharhinidae	<i>Scoliodon laticaudus</i>	+	+	+	NT
Myliobatiformes	Dasyatidae	<i>Urogymnus granulatus</i>	+	+	+	NT
Myliobatiformes	Dasyatidae	<i>Pateobatis bleekeri</i>	+	+	+	VU
Myliobatiformes	Dasyatidae	<i>Maculabatis gerrardi</i>	+	+	+	VU
Myliobatiformes	Dasyatidae	<i>Brevitrygon imbricata</i>	+	+	+	DD
Myliobatiformes	Dasyatidae	<i>Pateobatis jenkinsii</i>	+	+	-	LC
Myliobatiformes	Dasyatidae	<i>Himantura uarnak</i>	+	+	+	VU
Myliobatiformes	Dasyatidae	<i>Himantura undulata</i>	+	-	-	VU
Myliobatiformes	Dasyatidae	<i>Neotrygon kuhlii</i>	+	+	+	DD
Myliobatiformes	Dasyatidae	<i>Pastinachus sephen</i>	+	+	+	DD
Squaliformes	Echinorhinidae	<i>Echinorhinusbrucus</i>	+	+	-	DD
Myliobatiformes	Gymnuridae	<i>Gymnura japonica</i>	+	+	-	DD
Myliobatiformes	Gymnuridae	<i>Gymnura micrura</i>	-	+	-	DD
Myliobatiformes	Gymnuridae	<i>Gymnura poecilura</i>	+	+	-	NT
Orectoalobiformes	Hemiscyllidae	<i>Chiloscyllium arabicum</i>	+	+	+	NT
Orectoalobiformes	Hemiscyllidae	<i>Chiloscyllium griseum</i>	+	+	+	NT
Orectoalobiformes	Hemiscyllidae	<i>Chiloscyllium indicum</i>	+	+	-	NT
Lamniformes	Lamnidae	<i>Isurus oxyrinchus</i>	+	+	+	VU
Myliobatiformes	Myliobatidae	<i>Aetobatus flagellum</i>	+	+	+	EN
Myliobatiformes	Myliobatidae	<i>Aetobatus narinari</i>	+	+	-	NT
Myliobatiformes	Myliobatidae	<i>Mobula birostris</i>	-	+	-	VU
Myliobatiformes	Myliobatidae	<i>Mobula mobular</i>	+	+	-	EN
Rajiformes	Rajidae	<i>Orbiraja poeweli</i>	+	+	-	DD
Rhinopristiformes	Glaucostegidae	<i>Glaucostegus granulatus</i>	-	+	-	VU
Rajiformes	Rhinobatidae	<i>Rhina ancylostoma</i>	+	+	+	VU
Rajiformes	Rhinobatidae	<i>Rhinobatos punctifer</i>	+	+	+	DD
Chaimaeriformes	Rhinochimaeridae	<i>Neoharriotta pinnata</i>	-	+	-	LC
Myliobatiformes	Myliobatidae	<i>Rhinoptera javanica</i>	+	+	+	VU
Carcharhiniformes	Sphyrnidae	<i>Sphyrna lewini</i>	+	+	+	EN
Carcharhiniformes	Sphyrnidae	<i>Sphyrna mokarran</i>	-	+	-	EN
Carcharhiniformes	Sphyrnidae	<i>Sphyrnazyaena</i>	+	+	+	VU

CM-Chinnamuttom, CL-Colachel and V-Vizhinjam

The spatial variation in Shannon – Wiener diversity (H') value was given in the Table.2. The highest (H') value was observed at Colachel (4.17) followed by Chinnamuttom (4.11) and lowest at Vizhinjam (3.76). The spatial variation in Shannon-Wiener diversity (H') value were ranged between 3.76 -4.17 in Wadge bank, South India. The number of species was observed to be in the range of 26-44. A higher indices (5.66 - 5.94) was reported in Gulf of Mannar, South east coast of India(Gowthaman,2011). The diversity was lower at Wadge Bank, when compared to Gulf of mannar.

Species evenness: Evenness express how evenly the individuals in a community are distributed among the different species and it could be calculated by Pielous's evenness. The spatial variation in 'J' among the different stations was ranged from 0.77 to 0.80 (Table 2). The value was more than 0.75 in all stations, showing in high amount of evenness.

Species evenness was lower at Chinnamuttom than at Vizhinjam and it may be due to the high species richness

Table 2: Landing centre wise elasmobranchs diversity indices.

Landing Centre	S	N	d	J'	H'(log2)	Delta	sPhi+
Chinnamuttom	39	9531	4.07	0.78	4.11	60.3	1500
Colachal	43	10097	4.55	0.77	4.17	58.6	1720
Vizhinjam	26	5348	2.91	0.80	3.76	54.0	940

Table 3: Seasonal wise elasmobranchs diversity indices.

Seasons	S	N	d	J'	H'(log2)	Delta	sPhi+
Monsoon	37	4339	4.29	0.79	4.11	58.2	1440
Post-Monsoon	43	10490	4.64	0.84	4.64	60.7	1760
Pre-Monsoon	39	6731	4.31	0.70	3.70	56.7	1540
Summer	41	5066	4.42	0.77	4.20	59.7	1650

Table 4: Bray-Curtis similarity for landing centre wise at Wadge Bank, Southern India.

Chinnamuttom	Colachal	Vizhinjam
	98.99	
		83.63

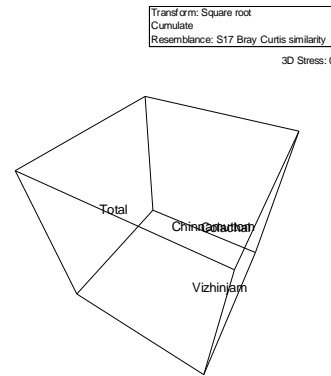
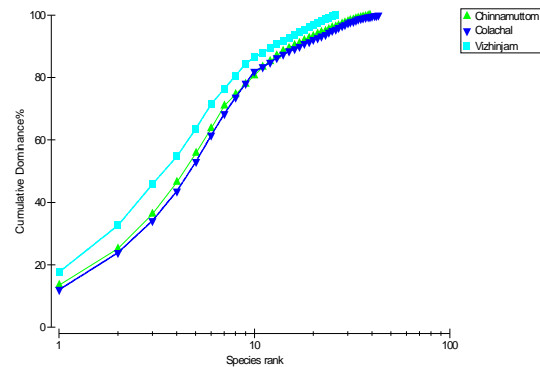
Table 5: Bray-Curtis similarity for seasonal wise at Wadge Bank, Southern India.

Monsoon	Post-Monsoon	Pre-Monsoon	Summer
	74.29	79.05	
		85.25	93.60

and dominance of individuals. The species evenness (J) was the lowest at Colachel. Similar high evenness have also been reported by the Jitendrakumar *et al*, (2015) and (Gowthaman, 2011) at Mangalore and Gulf of Mannar coast respectively. The evenness index (J') is strongly affected by species richness (Peet, 1974)

Taxonomic diversity (Δ): The estimated taxonomic diversity (Δ) values for the three landing centres are given in the Table 2. The spatial variation in taxonomic diversity indicates that the Vizhinjam (54.08) landing centre showed the lowest variation while the Colachel (60.3) showed the highest variation followed by Chinnamuttom (58.69).

Total phylogenetic diversity (sPhi+): The index denotes the taxonomic breadth/ total taxonomic path length and the average phylogenetic index are obtained by dividing the total phylogenetic diversity index by the number of species. In a healthy ecosystem, the total phylogenetic diversity will always be more (Table 2). The total phylogenetic diversity (sPhi+) value for Vizhinjam landing centre was 940 while the value was higher at Chinnamuttom landing centre (1500) and Colachel landing centre (1740). According to Gowthaman, (2011) for the elasmobranchs diversity, the phylogenetic diversity value was higher at Thoothukudi coast (2275-3125) followed by Mandapam (2250-2775) and Trichendur (1900-2525). When compared to the

**Fig 4:** Bray-Curtis similarities index on Square root transformed fish species data from three landing centres of Wadge Bank, South India.(MDS stress value 0.04).**Fig 5:** K-Dominance plot among three Landing Centres in Wadge Bank, South India.

phylogenetic diversity of Gulf of Mannar, the phylogenetic diversity at Wadge Bank is lower.

Bray-Curtis similarity: Bray-Curtis similarity is useful in quantifying the compositional similarity between two different sites, based on counts at each sites (Ajmal Khan *et al*, 2008). The highest similarity (98.97%) was occurring between Chinnamuttom and Colachel landing centres (Table 4). While analysing the seasonal variability in BC similarity index for whole Wadge Bank, it was found to be higher between pre-monsoon and post-monsoon in all the landing centres of Wadge Bank, whereas the lowest similarity has been observed between monsoon and post-monsoon season (Table 5). Gowthaman (2011) revealed that similar pre monsoon season BC similarities were observed at Gulf of Mannar. Station wise fish diversity was transformed in to square root to study the seasonal Bray Curtis similarities and the result is given in (Fig 4).

K-Dominance curve: The K-dominance curve was obtained by plotting percentage of cumulative abundance against species rank K on a logarithmic scale. The spatial variation, seasonal variation and the monthly variation in dominance plot among the three different landing centres of Wadge Bank, South India. Among the three landing centres, the Colachel landing centres has a relatively larger cumulative relative abundance than the other two landing centres (Fig 5).

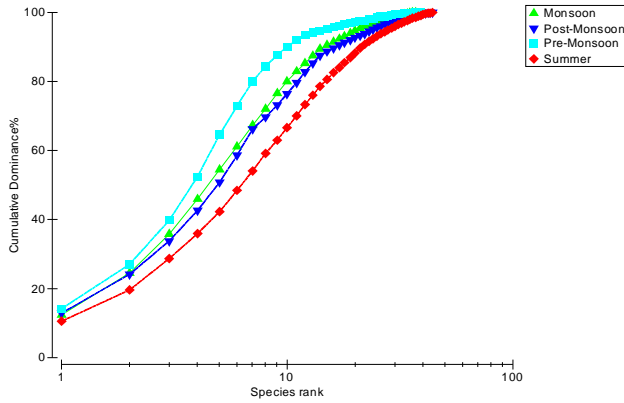


Fig 6: K Dominance plot among different seasons at Colachel Landing Centre.

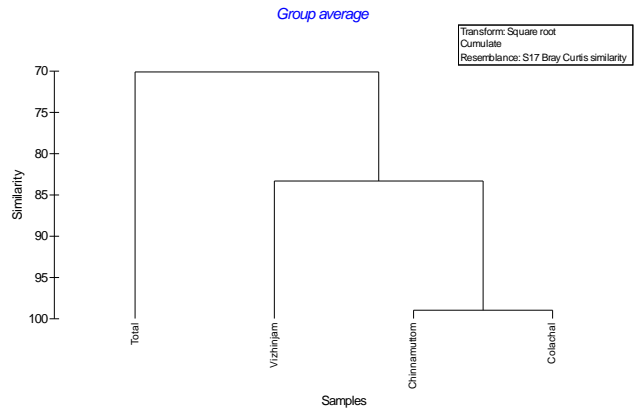


Fig 8: Dendrogram showing similarities between three landing centres based on the composition of fish species collected.

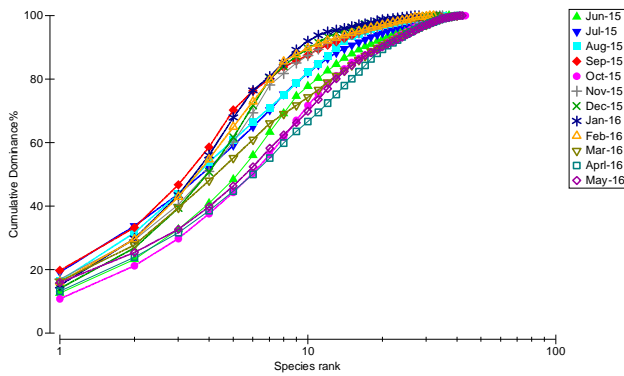


Fig 7: K-Dominance plot Month wise species distribution in Wadge Bank, South India.

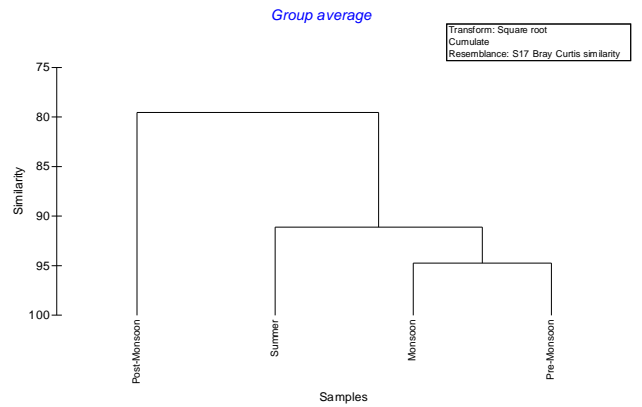


Fig 9: Dendrogram showing similarities between seasons based on the composition of fish species collected at Wadge Bank.

Post-monsoonal cumulative relative abundance was higher when compared to other seasons (Fig 6). The dominant plot showed that curve for month October 2015, which lie on the lower side, extended further and rise slowly due to high density of species. As the percentage contribution of each species was added, that curve extends horizontally before reaching the cumulative 100%. This plot showed that density of fish species and the number of species richness was more during October 2015 than other months (Fig 7). During the present study, the numbers of species collected were higher during the month of October and by seasons-wise, higher during post-monsoon period. While studying the ichthyofaunal diversity by Naomi *et al.*, (2011) from southern Kerala and Jitendrakumar *et al.*, (2013) from Mangaluru coast, the elasmobranch diversity was highest during post monsoon period. This might be due to aggregation of fish in coastal waters due to upwelling, a common phenomenon observed in the west coast during south west monsoon (Nair and Thampy 1980).

Cluster analysis: The purpose of cluster analysis is to organize the individuals into classes or groups such that within-groups and among groups similarities are analysed.

The dendrogram result revealed that greater similarities were observed between Chinnamuttom and Colachel landing centres due to the high species richness, Vizhinjam landing centre forms separate cluster (Fig 8). The similarities between seasons are revealed, the Post-monsoonal and summer season formed separate cluster (Fig 9). It is due to more abundance of species occurred in that season at Wadge Bank.

Conservation and management: In the present study, among the 44 species of elasmobranchs were recorded and 9% of them are under endangered category whereas 27% comes under vulnerable Category (Fig 3). Maturing *Carcharhinus melenopecterus* and *C. limbatus* were landed around the length group of 95 cm and 105 cm respectively at Vizhinjam and Colachel landing centre. These sharks have to be allowed to grow and spawn at least once to avoid recruitment overfishing. The juvenile size of *Rhina ancylostoma* and *Himantura undulata* were landed with the minimum length of 35 cm and 20 cm respectively at Colachel landing centre. To avoid growth overfishing these animals have to be allowed to grow. Since the species are captured in good numbers at smaller size and their reproductive potential is less, the conservation measures need to be

followed strictly. The resource management initiatives like the enhancing gillnet mesh size and hook and line size may be strengthened. Trawl net operation should be minimised along the Wadge Bank region. Further shark diversity rich hot spots should be identified and protected (Lucifora *et al*, 2011).

Elasmobranch conservation initiatives are at preliminary stage in India. These resources are playing important role in marine ecosystem and to protect these precious resources in Indian regions, study on elasmobranchs biology, aggregation sites and breeding has to be initiated.

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