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Sighting of cetaceans off Kochi: A spatial and temporal analysis

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ABSTRACT

The distribution of marine mammals in the Indian seas is poorly understood. The aim of this study was to use visual sighting survey to examine the distribution of cetacean species off Kochi, south-west coast of India. The relation between cetacean distribution and physiographic variables (depth and distance from the shore), oceanographic variables [sea surface temperature (SST) and sea surface salinity (SSS)] are also discussed. A total of 577 pods of dolphins were sighted from 625 fishing operations off Kochi coast during October 2018 to September 2019. In the encounters with 577 pods of dolphins, a total of 2599 individuals, represented by four species *viz*, *Sousa chinensis* (Indo-pacific humpback dolphin), *Stenella longirostris* (spinner dolphin), *Tursiops aduncus* (Indo-Pacific bottlenose dolphin) and *Delphinus capensis* (long beaked common dolphin) were recorded. A total area of 20,456.011 km^2 was covered in this survey and the distribution of cetaceans was plotted in grid and Shannon-Weiner diversity index was calculated. There was no significant difference in seasonal distribution of species in the study area, however sightings were less in the monsoon season compared to other seasons. Dolphins were observed in water depths ranging from 7 to 127 m, with majority of the sightings occurring in less than 50 m and between 3 and 65 km from the nearest shore. All the species were recorded at mean SST of 28°C and mean SSS of 34 ppt. The study shows the need for further research covering other locations along the Indian coast.

Keywords: Arabian Sea, Distance from shore, India, Seasonality, Sightings, Water depth

Introduction

The Indian Ocean is home to a wide variety of marine mammals, including the toothed whale, baleen whale, dolphin and dugong. The Indian EEZ supports 25 cetacean species (6 Mysticeti and 19 Odontoceti) and one Sirenian species, according to records of occasional cetacean stranding (Vivekanandan and Jeyabaskaran, 2012). According to the IUCN red list (http://www.iucnredlist.org), the 26 species of cetaceans recorded from Indian waters are categorised as endangered (4), vulnerable (3), near threatened (1), least concern (8) and data deficient (10). On the west coast of India, 21 species were recorded and eight species *viz,* spinner dolphin, Indo-Pacific bottlenose dolphin, long-beaked common dolphin, finless porpoise, Indo-Pacific humpback dolphin, blue whale, Risso's dolphin and sperm whale accounted for 94.6% of the total records (Kumarran, 2012). In a face to face survey with fishermen along the Indian coast, it was observed that the dolphins most frequently found were Indo-pacific humpback dolphin (*Sousa chinensis)* (27.6%), spinner dolphin (*Stenella longirostris*) (22.5%), long beaked common dolphin (*Delphinus capensis*) (19.7%) and Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) (15%) (Joseph *et al*., 2021). There has been scanty research on the occurrence and distribution of cetaceans in the eastern and north-eastern Arabian Sea and systematic studies to map their distribution is lacking (Alling, l986; Sutaria and Jefferson, 2004). Researchers are also not consistent on the actual number of cetacean species present in Indian seas (Kumaran, 2002).

In the context of the growing number of interactions of cetaceans with the fishing gears during operations in the Indian coastal waters, a detailed study was undertaken to find out occurance of cetaceans, extent of cetacean interaction with fishing gears and mitigation measures to reduce damage of gear. This communication deals primarly with cetacean sightings off Kochi, along the south-west coast of India. Due to limitations of conducting/participating in observer programs and as the study pertains to the fishing sector, sighting data were collected from fishing cruises. The objective of the study is to analyse the cetacean sightings off Kochi in terms of diversity, spatial and temporal distribution and also to study the distribution of cetaceans with reference to physiographic and oceanographic variables

Materials and methods

The sighting surveys were undertaken onboard commercial fishing vessels operated from Njarakkal, Chellanam (Ernakulam) and Neendakara (Kollam).

Cetacean sightings were recorded from 625 fishing vessel operations from October 2018 to September 2019 in the the area between 8°N-11°N and 74°E-77°E. The sightings observed is the sum total from 18 ring seine vessels and six gillnet vessels while cruising to the fishing grounds and during fishing. The length overall (L_{OA}) of ring seine fishing vessels ranged from 19-22 m and that of gillnetting vessels ranged from 6 to 9 m. The observation days were not equally distributed between the seasons. Data were collected in three seasons *viz,* post-monsoon (October-January), pre-monsoon (February-May) and monsoon (June-September). The information were collected through a pretested questionnaire. One person from each vessel acted as observer through the fishing operation. The first author participated in 40% of the fishing operations for data collection and the rest of data were collected by the captain/bosun/fishermen of the selected fishing vessel, who were also experienced/trained in identifying the species and they acted as observers. A dedicated person from each vessel was given aids like identification card (Braulik, 2018) and blown up coloured photographs of the commonly occurring dolphins. Besides they had prior experience in witnessing the interaction of dolphins with fishing gears and were adept at identifying the different species by their locally known names. Binoculars (Nikon action EX 10x50 CF) was used for recording observations in 40% of the observations and rest were based on visual observations backed by years of experience. The key characteristics used for identification of the most commonly occurring dolphins are given in Table 1.

Cetacean distribution data, as well as related oceanographic and physiographic factors, were also collected. To record the appropriate sighting data, the study used a standard technique proposed by the South-west Fisheries Science Center (SWFSC) (Kinzey *et al*., 2000). Date and time of cetacean sighting, geographical position of sighting, distance between the sighting and the nearest shore were recorded. Global Positioning System (GPS) was used to record geographical position of animal sighted area. Mapping and plotting of the data was done using ArcGIS software.

For studying the geographical distribution, relative abundance and diversity analysis in the surveyed region (8°N-11°N and 74°E-77°E), it was further divided into 12 x 12 nautical miles (nm) grids. Cetacean sightings were distributed in 49 grids (35 full grid squares, 10 half grid squares, 3 quarter squares and one ¾ grid square), to investigate species richness within the study areas (Fig. 4). Survey effort was calculated for every grid and summed for the total survey effort for each region (Table 3). Area of a single grid was 144 nm^2 (12 nm x 12 nm). Seasonal variation in cetacean diversity and distribution was assessed across all surveyed areas. Shannon-Weiner *(H)* index was used to estimate diversity (Shannon-Weiner, 1963).

In the present study, four variables *i.e.* two physiographic variables (depth and distance from the shore) and two oceanographic variables (sea surface temperature [(SST) and sea surface salinity (SSS)] were considered to study habitat characteristics of each species sighted. SST and SSS values were obtained from GIOVANNI data and contour map software. Descriptive statistics such as mean, standard deviation, as well as inter-quartile deviation were calculated and plotted in Box Whisker Graph. The species distribution in relation to oceanographic and physiographic variables was tested using the Kruskal-Wallis test (Kruskal and Wallis, 1952). Statistical analyses were conducted with the statistical software XLSTAT 2020, version 22.1.6.

Results and discussion

A total of 577 pods of dolphins were sighted from 625 fishing operations off Kochi coast and the number of dolphins ranged from 1-50 during each sighting. Altogether a total of 2599 individuals, represented by four major species were recorded. The species recorded were *S. chinensis* (Indo-Pacific humpback dolphin), *S. longirostris* (spinner dolphin), *T. aduncus* (Indo-Pacific bottlenose dolphin) and *D. capensis* (long beaked common dolphin). In 6250 h of sighting effort, 0.40 individuals were sighted per hour (4.06 sighting per day). The study

Table 1. Scientific, common/local names and key identification characteristics of identified dolphins

Scientific name	Common/local name	Key identification characteristics
Sousa chinensis	Common name: Indo-pacific humpback dolphin, Local name: Paandanpanni	Pink pigmentation and light coloured body
Stenella longirostris	Common name: spinner dolphin, Local name: Meliyaneti	Spinning behaviour, dark stripe extending from the eye to the flipper, beak tip and lips are dark
Tursiops aduncus	Common name: Indo-Pacific bottlenose dolphin, Local name: Kuppimukkan	Dark ring present around the eyes, belly marked with speckles or black spots
Delphinus capensis	Common name: Long beaked common dolphin, Local name: Kaṭalpanni	Dark lines from flippers to the bottom of the lower jaw, dark brown above, including the dorsal fin

conducted in Indian EEZ by Yousuf (2009) reported 0.7 sightings per day. In the north-west Indian Ocean and Sri Lankan waters, Ailing (1986) reported that sightings were 0.9 per day. Ballance and Pitman (1998) reported 6.4 sightings per day in westem tropical Indian Ocean. The most common species observed during the present study was *S. chinensis* and the least observed species was *T. aduncus* (Table 2). On the whole, the cetaceans were sighted between 8°N-11°N and 74°E-77°E.

Group sizes varied extensively among the different species, with *S. chinensis* having the largest sightings. At times, the same species was observed in small groups also, ranging from 1 to 8 individuals. *S. longirostris* was seen within a group of *S. chinensis*. *T. aduncus* had widely ranging group sizes between 1 and 50 individuals. Sightings of species off Kochi are shown in Fig. 1.

Table 2. Number of sightings and counts of individuals

Species	$n_{sightings}$	$n_{animals}$
S. chinensis	366	1637
S. longirostris	121	530
T. aduncus	23	162
D. capensis	67	270

S. chinensis sightings were recorded in 8-11^{0}N/76-5^{0}E throughout the study. Three hundred and sixty six *S. chinensis* sightings were recorded, comprising a total of 1637 animals. The numbers of animals ranged from

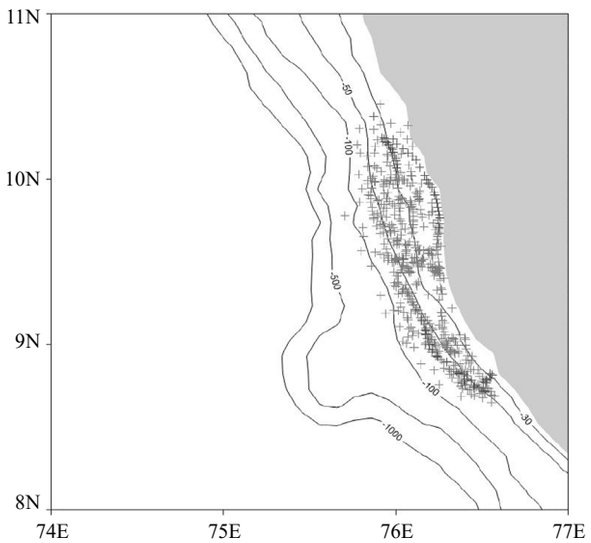

Fig. 1. Sightings of cetaceans off Kochi coast of Arabian Sea

Table 3. Species richness and diversity along the 12 x 12 nm grids

Area	Grid No.	Position	S	N	H
Arabian Sea off Kerala Coast	35	8.6 - 8.8 N/76.3 - 76.5 E	53	223	0.90
	34	8.6 - 8.8 N/76.1 - 76.3 E	1	5	0.00
	36	8.8 - 9.0 N/76.3 - 76.5 E	43	197	1.00
	33	8.8 - 9.0 N/76.1 - 76.3 E	26	103	0.92
	1	9.0 - 9.2/76.3 - 76.5 E	10	41	0.65
	32	9.0 - 9.2/76.1 - 76.3 E	44	183	0.87
	25	9.0 - 9.2/ 75.9 - 76.1	12	54	0.59
	31	9.2 - 9.4/76.3 - 76.5	1	6	0.00
	24	9.2 - 9.4/76.1 - 76.3	18	92	0.64
	25	9.2 - 9.4/75.9 - 76.1	29	163	0.69
	30	9.4 - 9.6/76.3 - 76.1	58	219	0.31
	23	9.4 - 9.6/75.9 - 76.1	46	251	0.89
	14	9.4 - 9.6/75.7 - 75.9	3	12	0.00
	29	9.6 - 9.8/76.1 - 76.3	29	134	0.77
	22	9.6 - 9.8/75.9 - 76.1	43	225	1.09
	13	9.6 - 9.8/75.7 - 75.9	9	49	0.00
	28	9.8 - 10.0/76.1 - 76.3	28	110	0.68
	21	9.8 - 10.0/75.9 - 76.1	48	206	0.61
	12	9.8 - 10.0/75.7 - 75.9	16	65	0.13
	9	10.0 - 10.2/76.1 - 76.3	3	17	0.00
	20	10.0 - 10.2/75.9 - 76.1	28	118	1.09
	11	10.0 - 10.2/75.7 - 75.9	10	47	0.00
	19	10.2 - 10.4/75.9 - 76.1	13	62	0.96
	10	10.2 - 10.4/75.7 - 75.9	5	12	0.28
	3	10.4/75.9 - 76.1	1	5	0.00

S-Sightings, N-Total individuals, H - Shannon index

single individuals (63.3% of sightings) to 18, with a mean group size of 4.4 (SD = 2.6). In Indian waters, two types of *Sousa* species have been documented, *S. chinensis* and *S. plumbea*. *S. chinensis* do not have a prominent hump and has pink pigmentation and a light coloured body. *S. plumbea* has a large hump and appear dark grey in colour (Sutaria and Jefferson, 2004). According to Afsal *et al*. (2008), the maximum group size of *S. chinensis* in Cochin backwaters and the Cochin bar mouth is 3.6. According to Yousuf (2009), the average group size was 3.6 in Indian waters and the highest population group size of 3.9 was observed in Gulf of Kutch.

S. longirostris sightings were recorded throughout the study in the area 8-10^{0}N/76-75^{0}E, *i.e.* off Kochi and Alappuzha coast. One hundred and twenty-one (121) sightings were recorded, with a total of 530 animals. Single individuals (21.1% of sightings) to 20 animals were observed, with a mean group size of 4.3 animals (SD=3.1). The distribution of *S. chinensis* and *S. longirostris* are shown in Figs. 2a and b. The geographical distribution of sightings and stranding suggests that this species is widely distributed along the Indian coast. Studies in neighbouring seas, such as the western tropical Indian Ocean and the Maldives reported both species as frequently sighted and most abundant species (Ballance and Pitman, 1998; Ballance *et al.,* 2001). Perrin *et al*. (1999) documented *S. longirostris* and *S. roserventris* in northern Indian Ocean. Of the two species, only the former was observed in the present study.

T. aduncus sightings were recorded throughout the study, in the area 8-10^{0}N/76-75^{0}E. Sixty seven (67) sightings were recorded, with a total of 270 animals. One (11.5% of sightings) to 13 animals were observed, with a mean group size of 4.0 (SD = 2.5). *T. aduncus* and *T. truncatus* are the two different species of bottlenose dolphins seen in the Indian Ocean (Hale *et al*., 2000). Only *T. aduncus* was sighted in the surveyed area and significant sighting of this species was recorded in near shore areas. Genetic studies conducted by Jayasankar *et al*. (2007) from Vizhinjam, south-west coast and Chennai, south-east coast of India, confirmed that the bottlenose dolphin in the Indian seas is *T. aduncus*. Studies by Yousuf (2009) reported that the mean group size of *T. aduncus* was 12.

D. capensis sightings were recorded throughout the study in the area 9^{0}N-76^{0}E. Twenty three (23) sightings were recorded, comprising a total of 162 animals. In each pod, one (3.9% of sightings) to 50 animals, with a mean group size of 7 (SD = 10.3) were observed. Largest group size was 10-50. The distribution of sightings of *T. aduncus* and *D. capensis* are shown in Figs. 3a and b. Very few sightings of *D. capensis* were reported in the Bay of Bengal, Andaman Sea and north of the Arabian Sea (Yousuf, 2009). This species was recorded in FORV Sagar Sampada cruise (1987 and 1989) by Jayaprakash *et al.* (1995) in the northern Bay of Bengal. Also, their presence in the Gulf of Mannar was recorded by Alling (l986) during the survey "Tulip expedition" in the waters of Sri Lanka. Landings of this species have also been reported from northern Bay of Bengal and other surveyed areas (Lalmohan, 1985; Pillai and Chandrangathan, 1990; Chandrakumar, 1998; Yousuf *et al.*, 2008). According to Lalmohan (1985), it is the third abundant species off Calicut coast.

Sightings of cetaceans were recorded in all the 49 grids, during the present study. Total area covered in

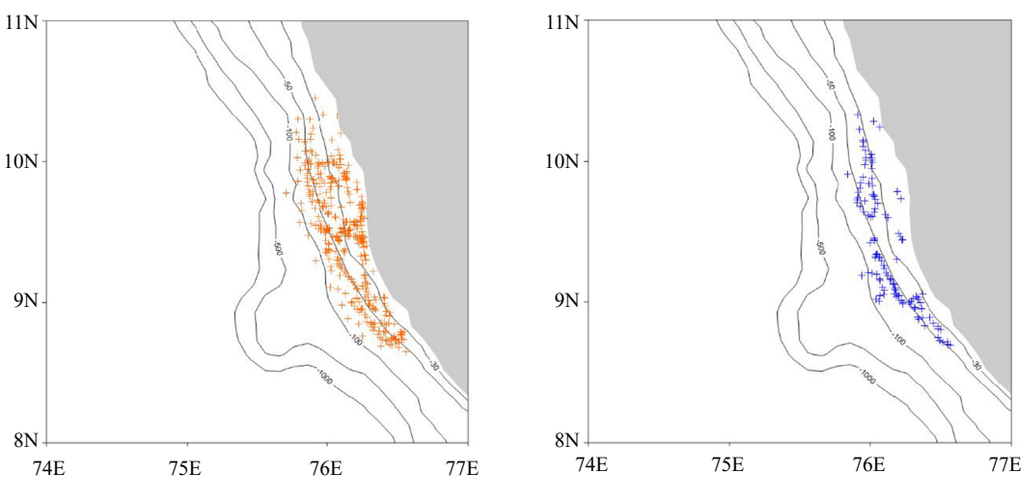

Fig. 2. Distribution of sightings of (a) *S. chinensis* and (b) *S. longirostris*

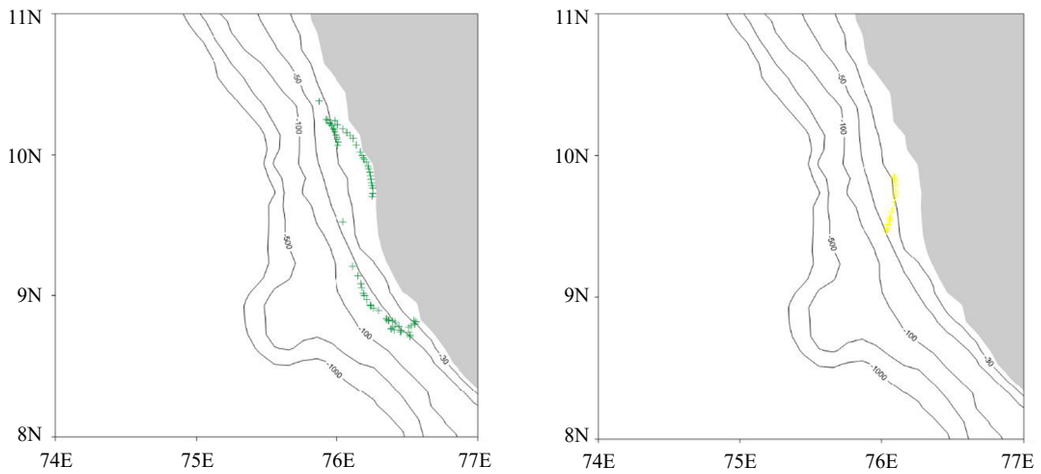

Fig. 3. Distribution of sightings of (a) *T. aduncus* and (b) *D. capensis*

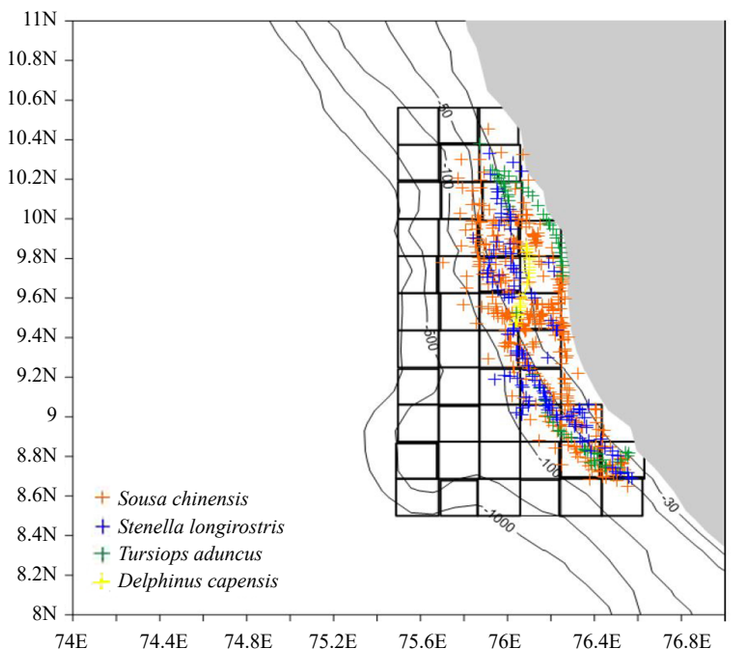

Fig. 4. Individuals recorded in each 12 x 12 nm grid of surveyed areas

the survey was 20,456.011 km^2. In the study area, the maximum number of sightings was in G30 (9.4°N - 9.6°N and 76.3°E - 76.1°E). Maximum individuals were observed in G23 followed by G22 (Table 2).

Shannon-Weiner diversity index calculated for each 12 x 12 nm grid is given in Table 2. When compared to other areas, the positions 9.6-9.8/75.9-76.1 and 10.0-10.2/75.9-76.1 showed the highest species diversity. G20 (1.09) and G22 (1.09) had the highest Shannon diversity values. The area with the lowest Shannon richness value was found in G12 (0.13) and G10 (0.28) in positions 9.8-10.0/75.7-75.9 and 10.2-10.4/75.7-75.9.

Pre-monsoon season accounted for maximum sightings followed by post-monsoon and monsoon seasons. Altogether, maximum number of sightings was in April (pre-monsoon) with sighting frequency of 0.52 h^{-1}, while the minimum number of sightings was in August (monsoon) with sighting frequency of 0.27 h^{-1}.

Sightings per day and per hour was maximum in November (post-monsoon) and lowest in August (monsoon). The reason for maximum cetacean sighting in pre-monsoon is probably because the seawater is very clear and in monsoon season after rains the seawater becomes turbid. Sightings were generaly less during monsoon season. When the sea is rough, sighting the animal is difficult due to high wave conditions. This may be one of the reasons for less sightings during monsoon. There was no significant difference in seasonal distribution of species in the study area. Sighting rate during different seasons are given in Table 4. Figs. 5 and 6 depict seasonal sighting records and the observed number of individuals in the study region.

A total of 1286 (49.4%) individuals were sighted in pre-monsoon, 865 (33.2%) in post-monsoon and 448 (17.2%) in monsoon seasons. *S. chinensis* was the dominant species in all the seasons. *T. aduncus* was more common than the other three species in the post-monsoon season. In pre-monsoon, *S. longirostris* was the dominant species. The third most frequent species was *D. capensis*.

With regard to depth of water where different species were sighted, significant difference was recorded

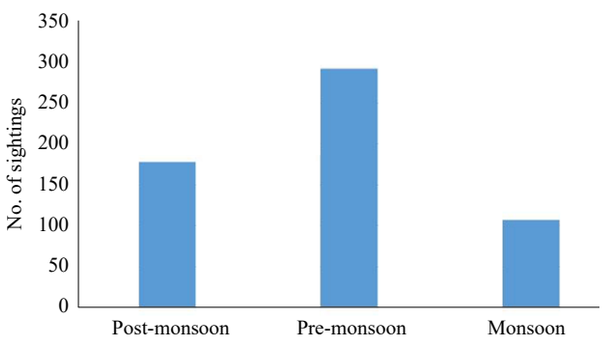

Fig. 5. No. of sightings in different seasons

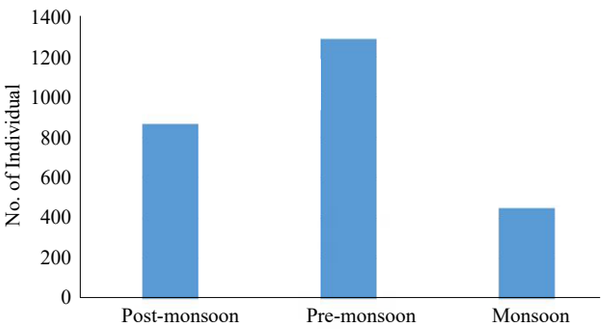

Fig. 6. No. of individuals recorded in different seasons

(KW = 23.17, df = 3, p = <0.0001). Dolphins were sighted in the water surface, where depth ranged from 7 to 127 m (Fig. 7). (mean = 41.27, SD = 17.43, *n* = 577), with the majority of sightings with in less than 50 m. *S. chinensis* was found in groups ranging from 1 to 20 individuals throughout a wide range of water depth (10-50 m). *S. longirostris* is considered to prefer shallow waters, less than 50 m depth. *T. aduncus* was found in water having depth ranging from 10-50 m. *D. capensis* was seen in groups ranging from 1 to 50 individuals throughout a wide range of water depth (20-50 m) (Fig. 8). According to the observations during the study it is clear that dolphins are more close to the shore with in a depth range of 0-49 m. *S. chinensis* are more closer to the shore (*n*=234), followed by *S. longirostris* (*n*=76). Only less number of species are seen above 100 m depth (*n*=5).

Cetaceans were observed in the study area at distances ranging from 3 to 65 km from the shore. A total of 326 sightings (56.4%) were recorded between 19 and 27 km from the shore. The distance between the nearest coast to the distribution of cetaceans ranged from 3 to 65 km. There was significant difference (KW=29.95, df=3,

Table 4. Sighting rate of cetaceans during different seasons

Season	Month	Observation effort		No. of days of sighting	No. of sightings	Sightings per day	Sightings per hour
		Days*	Hours				
Post-monsoon	October	43	430	34	205	4.77	0.48
	November	46	460	42	243	5.28	0.53
	December	52	520	52	235	4.52	0.45
	January	54	540	50	182	3.37	0.34
Pre-monsoon	February	63	630	57	219	3.48	0.35
	March	77	770	77	293	3.81	0.38
	April	74	740	74	388	5.24	0.52
	May	84	840	84	386	4.60	0.46
Monsoon	June	26	260	22	117	4.50	0.45
	July	34	340	27	101	2.97	0.30
	August	29	290	26	78	2.69	0.27
	September	43	430	32	152	3.53	0.35

*Days indicate total fishing days in a month for all fishing vessels put together

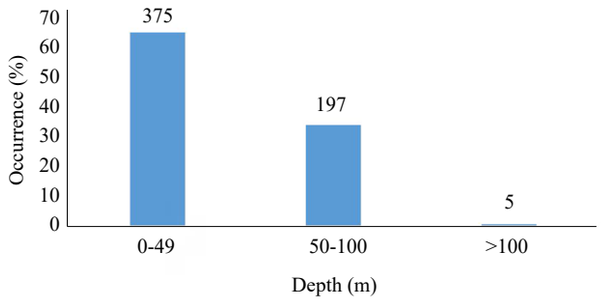

Fig. 7. Depth of dolphin sightings (n=577) between October 2018 to September 2019 in the Arabian Sea off Kerala Coast. Numbers above the bars represent the sample number (n)

p=<0.0001) with regard to distance and species. Among the cetaceans, *D. capensis* and *S. chinensis* were frequently observed in shallow waters with a few observations in deeper waters. Sighting of *S. chinensis* ranged from 4-63 km with deep oceanic water observation, whereas it ranged from 8 to 54 km with in a mean distance of 29 km (SD=9.73) for *S. longirostris*. *T. aduncus* was mostly found in shallow water with a few sightings in deeper waters, with majority of the sightings from 18-37 km distance. *S. chinensis* sightings were commonly from coastal waters and was observed only on a single occasion in deep water at a distance of 65 km from the nearest shore.

S. chinensis, as reported elsewhere (Corkeron *et al*., 1997; Jefferson and Leatherwood, 1997), prefer shallow depth between 10-50 m. Yousuf (2009) reported that,

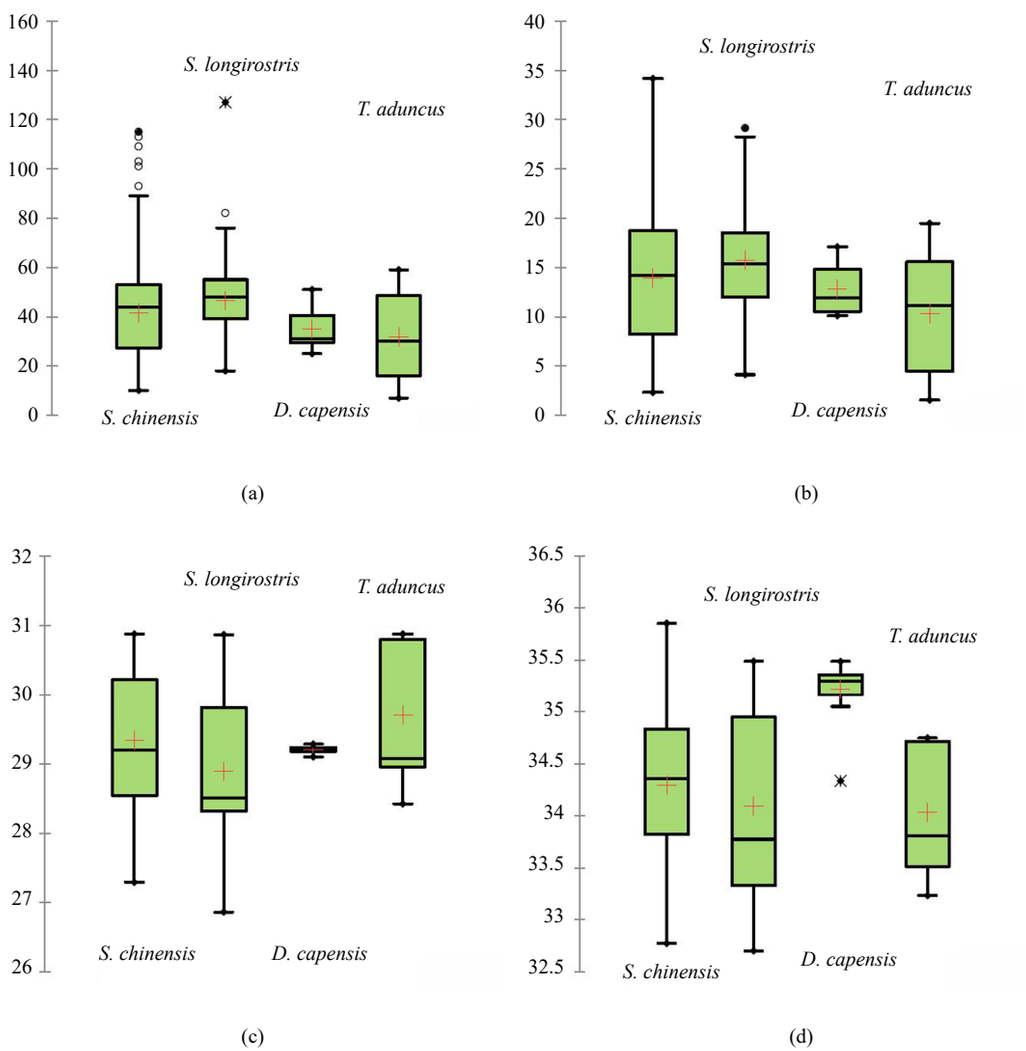

Fig. 8. Cetacean distribution observed during the survey with respect to depth (m), distance from shore (km), temperature (°C) and salinity (ppt)

S. chinensis sightings were in shallow waters at depths of <20 m and within 0.5 km. The distribution pattern observed in this study is similar to the observation by Sutaria and Jefferson (2004) in north-eastern Arabian Sea. *S. longirostris* is commonly an oceanic cetacean, but it can also be seen in shelf areas (Jefferson *et al*., 1993). In the present study, this species was sighted upto 127 m on the continental slope in deeper oceanic waters but irregularly found over shelf and shelf break water within 7.6 km from the shore. Karbhari *et al*. (1985) observed the presence of squids and carangids in the stomach of *S. longirostris,* which indicates that this species utilise shallow water in shelf area for feeding. *T. aduncus* preferred the shelf and shelf break, although it was also found on continental slope in offshore area (Azzellino *et al*., 2008). It was observed that *T. aduncus* occurred within the depth of 50 m and within 37 km from the nearest coast. A study conducted by Mohammed *et al*. (2006) on the stomach contents of *T. aduncus* has shown diverse range of fish, cuttlefish, cephalopods, copepods and squilla. Hence, the wide distribution observed in the shelf area may be the result of its prey preference (Yousuf, 2009). Distribution of *D. capensis* with respect to depth and occurrence from the nearest shore was intermediate between *T. aduncus* and *S. longirostris* distribution (Afsal *et al*., 2008). In the present study, *D. capensis* and *S. chinensis* were constantly sighted in coastal waters with a few sightings in oceanic waters. According to Di Tullio *et al*. (2016), most of the sightings of the same species were over shelf and shelf break area in offshore waters with only a few sightings from coastal shelf waters.

The SST recorded during the present study ranged from 27 to 31°C. All the species occurred in mean SST of 28°C. With regard to SST and species sightings, there was significant difference (KW=38.1, df= 3, p=<0.0001). *S. chinensis* and *T. aduncus* sightings were limited to SST between 27 and 31°C and 29°C respectively. *S. longirostris* and *D. capensis* occurred in water with wide range of variation in SST from 26 to 30°C. The SSS in the study area varied from 32 to 35 ppt. Significant difference was also recorded with respect to species sightings and SSS (KW=52.4, df=3, p=<0.0001). The three dominant species namely *S. chinensis*, *S. longirostris* and *D. capensis* were sighted at salinity ranging from 32 to 35 ppt.

The cetaceans were found with comparatively narrow range of SST and SSS (Yousuf, 2009), similar to the work done by Fritts *et al*. (1983) in northern Gulf of Mexico and Au and Perryman (1985) and Perrin and Gilpatrick, (1994) in eastern tropical Pacific. Except *S. longirostris*, all other cetacean species were observed with mean SST of 28°C and average SSS of 32 to 35 ppt. *S. chinensis* sighted areas were characterised by low SST and SSS, which agree with the observation of Smith *et al*. (2008) off Bangladesh. SSS of all the species sighted during the study was within the range of 32 - 35 ppt, which supports the observations of Yousuf (2009). The oceanographic variables varied with the depth and therefore, the influence of oceanographic variables on distribution of cetaceans may be the consequence of their depth of distribution (Yousuf, 2009).

Cetacean distribution with respect to depth, distance from shore, temperature and salinity observed during the study were represented by Box and Whisker plot showing median, quartiles and extreme values (one box plot per species is displayed) (Fig. 8).

The most common species sighted in the coastal waters only have been mentioned in this communication. The species distribution pattern reported in this study agrees with historical data based on incidental capture. The information generated on species sightings and distribution will be valuable in estimating the richness of marine mammals off Kochi. To estimate the distribution of missing coastal species in the current study, onboard surveys are to be supplemeted with exclusive coastal surveys. Seasonal distribution of marine mammals in different geographical locations are also to be studied extensively. The findings of the current study suggest further elaborate investigations along the Indian coast. When considering conservation measures or prospective MPAs (Marine Protected Areas), it is important to take into account the mean abundance of marine mammals.

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